Mónika Gácsi

LOOKING AT THE PAST THROUGH MEDIEVAL GLASS

Medieval Glass Workshops in the Carpathian Basin

MA Thesis in Late Antique, Medieval and Early Modern Studies

Central European University

Budapest

May 2022

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Medieval Glass Workshops in the Carpathian Basin

by

Mónika Gácsi

(Hungary)

Thesis submitted to the Department of Medieval Studies,
Central European University, Budapest, in partial fulfillment of the requirements
of the Master of Arts degree in Late Antique, Medieval and Early Modern Studies.

Accepted in conformance with the standards of the CEU.

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I, the undersigned, **Monika Gacsi**, candidate for the MA degree in Late Antique, Medieval and Early Modern Studies, declare herewith that the present thesis is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

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Abstract

The thesis focuses on the working process and technology of medieval glassmaking. This analysis covers the glass production sites of the eleventh - sixteenth centuries. The geographical frame is the medieval Kingdom of Hungary, meaning modern-day Hungary, parts of Austria, Slovakia, Slovenia, Romania, Croatia, Serbia, and Ukraine, but parallels are quoted from other parts of medieval Europe.

The aim of this thesis is to examine how a medieval glass workshop functioned and what were the basic needs of a production site to manufacture glass products in the medieval Hungary. Therefore, the first chapter evaluates written and visual sources on glassmaking technologies, furnaces and needs of a functioning workshop. The second chapter collects the indicators of a glasswork site and analyses the written sources. This part also uses reports of the non-destructive archaeological surveys. The third chapter studies the excavated sites (Pásztó, Diósjenő, Pomáz – Nagykovácsi, Visegrád – 5 Rév Street) and reviews their place in the traditional typology. The fourth chapter investigates the installation factors of a glass workshop like water, firewood, and raw materials; as well as the connections to roads, potteries and smithies. The last chapter of the thesis summarizes the social status of glaziers and their working conditions.

In its conclusion, the thesis discusses glass workshops from different viewpoints, including the spatial distribution of the sites and the production landscape. These approaches were hitherto less common in the Hungarian research. The analyses of these, the context and the environment of medieval glasswork demonstrate that the sites were selected on the basis of a set of criteria, including environmental conditions, road systems, market opportunities and the presence of other economic activities.

Acknowledgements

I would like to say special thanks to my supervisors, József Laszlovszky and Alice Choyke for their kind guidance, patience, and unwavering support in the past years. I am grateful to Zsuzsa Reed for her help and writing advice. I owe thanks to Katalin Szende, for her encouraging words. I would also like to thank Károly Magyar for his support and enthusiastic literature searches. I am also indebted to my family for their encouragement along the way. And lastly, I am deeply grateful for Eszter Magyar, Gergely Szoboszlay and Vania Buso for their support and friendship.

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Introduction

The delicate art of glassmaking was one of the most difficult and complex crafts of the Middle Ages. To properly operate, a glass workshop was dependent on its sturdy kilns as well as on its trade connections. It needed continuous supplies and skilled glass-blowing masters and workers. Therefore, a study of the medieval workshops of glass production requires a complex approach and an interdisciplinary methodology. To understand the landscape of medieval glass production this thesis not only will examine the workshop's physical structures but also their surrounding environment and connections to settlements and other crafts.

The spatial framework of this research is the territory of the medieval Kingdom of Hungary, the Carpathian Basin: this refers today to modern-day Hungary as well as parts of Croatia, Slovakia, Slovenia, Austria, Romania, Serbia, and Ukraine. The time frame of this work stretches between the eleventh and the sixteenth centuries.

The particular aim of this thesis is to examine the glassmaking process in the medieval workshops in the Carpathian Basin including, not only the furnace types and physical layout of the workshops, but also the surrounding environment and installation factors. A considerable literature has been published on medieval glass workshops in the Carpathian Basin. These works have focused on the archeological features, relevant written sources or on the production technology. The authors took into consideration many different aspects; however, this thesis is the first in-depth analysis that examines the furnace types and site layouts of the workshops in the context of site selection process.

The research data in this thesis is drawn from primary and secondary written sources, images depicting workshops or the process of glassmaking and historical, cadastral maps. It also revisits previous research on this topic. The maps (Figures 16-17, 54-55, 57-63) that present the spatial distribution of glass workshops were created with QGIS based on historical

and archaeological data. These maps are important tools for data visualization as well as, for data analysis. The large scale spatial distribution pattern of workshops as well as the location and setting of individual workshops in their local contexts offer valuable data on the complex interpretation of glass production centers.

As a result of this investigation, the thesis has been divided into five parts. The first chapter deals with extant written and visual sources for medieval glassmaking technologies and explores the limits of the information that can be obtained from them. The second chapter contains an analysis the use of written sources on glass workshops and non-destructive archaeological surveys. This part deals with indicators marching the presence of glass working site as well as various criteria for detecting workshops in conducted surveys and small excavations. The third chapter reviews furnaces and structures found in excavated glass workshops in the region. The fourth chapter investigates the different needs and the installation factors of a glass workshop. The fifth chapter contains an assessment of the scarce information available concerning the everyday life and social status of the glassworkers. Based on these different source materials and research approaches, the conclusion of this thesis offers an overview on the landscape setting and surrounding environment of workshops in the territory of the medieval Hungarian Kingdom.

Research trends, research questions

The important role of the context, connections and work environment of a glass workshop is not a widely studied research problem in Hungary. Possibly the most in-depth study was conducted by Edit Megyeri. In her MA thesis, in which she mainly focused on the

glass products from Visegrád- 5 Rév Street and Pomáz-Nagykovácsi puszta. However, she also analyzed the structure of these two workshops structure and their installation factors. [1]

This research approach, at the same time, can be compared to studies on glass production in various areas of medieval Europe. For example, significant research has been carried out on medieval workshops in England. In a publication on medieval glass vessels, R. J. Charleston evaluates the written and visual sources while examining the excavated sites and archaeological finds. He also emphasizes the importance of any given glass workshop's access to raw materials, fire resistant clay and other craft activities such as smithing or pottery.[2] In another article, he classifies both the southern and northern glassworks in Europe by examining treaties and excavations from the Roman period to the seventeenth century.[3] Other publications examine the way forest glass production in Blunden's Wood (c.1330), Knightons (c. 1550) and Sidney Wood(1600-1620) operated. The publication also provides a deeper understanding of the technology used there and how the furnaces operated, while attempting to reconstruct the workshops themselves.[4] Colin Jeremy Clark, in his doctoral dissertation, analyzed the glassworks in the Weald region. He describes the sites and furnaces and also outlines their methods of accessing raw materials needed in different aspects of glass production such as wood, and clay while also emphasizing the economic impact of glassmaking.[5] This example is also important for the Hungarian material because the Weald region was also significant center

[1] Edit Megyeri, "Üvegleletek a visegrádi és a pomázi késő középkori üveggyártó műhelyekből [Glass Findings from the Late Medieval Glass Workshops of Visegrád and Pomáz]" (MA Thesis, Budapest, Eötvös Loránd University, 2015); Edit Megyeri, "Üvegek a Visegrád Rév utca 5. szám alatt feltárt üvegműhelyből és Pomáz–Nagykovácsi lelőhelyről [Glass Finds from the Glass Workshop at 5 Rév Street Visegrád and at the Excavation Site of Pomáz–Nagykovácsi]," in *A múltnak kútja. Fiatal középkoros régészek V. konferenciájának tanulmánykötete [The Fountain of the Past. Study Volume of the Fifth Annual Conference of Young Medieval Archaeologists]*, ed. Tibor Ákos Rácz (Szentendre: Ferenczy Múzeum, 2014), 75–89.

[2] R.J. Charleston, "Vessel Glass," in *English Medieval Industries. Craftsmen, Techniques, Products*, ed. John Blair and Nigel Ramsay (London: Hambledon Press, 1991), 237–64.

[3] R.J. Charleston, "Glass Furnaces through the Ages," *Journal of Glass Studies* 20 (1978): 9–33.

[4] Ian James Merchant, "English Medieval Glass-Making Technology: Scientific Analysis of the Evidence" (Ph.D. Dissertation, Sheffield, The University of Sheffield, 1998); Eric S. Wood, "A Medieval Glasshouse at Blunden's Wood, Hambledon, Surrey," *Journal of the Surrey Archaeological Society*, no. LXVII (1965): 54–79.

[5] Colin Jeremy Clark, "The Glass Industry in the Woodland Economy of the Weald" (Doctoral Dissertation, Sheffield, University of Sheffield, 2006).

of iron production in the Middle Ages. The most comprehensive analysis of the glass workshops sites in Germany, France, Italy, Greece, the Czech Republic and England was carried out by Peter Kurzmann. His research focusses on the importance of raw materials, wood and water supplies while classifying the furnace types, glassware, and excavated sites across Europe.[6] Peter Steppuhn also researched glass workshops in depth across Germany. He has numerous papers on glass products from the eleventh century to the seventeenth century as well as detailed reports on the glass workshops, that he excavated. His monographic, interdisciplinary study on a medieval region offers an overview of glass production in the context of other crafts and production branches.[7] A comprehensive excavation and study were carried out by Aline Kottmann and Sören Frommer in Schönbuch forest (Baden-Württemberg). The well-preserved remains of this glass workshop were connected to the near Cistercian monastery of Bebenhausen. In their book, Kottmann and Frommer examined the facilities, the glassmaking process and the economic background to the workshop site.[8] In Slovakia and in the Czech Republic, Hedvika Sedláčková and Eva Černá investigate medieval glass finds, excavated sites and their features.[9] Kinga Tarcsay has several publications on medieval

[6] Peter Kurzmann, *Mittelalterliche Glastechnologie. Archäologie - Schriftquellen - Archäochemie - Experimente* (Frankfurt am Main: Peter Lang GmbH, 2004).

[7] Peter Steppuhn, "Archäologie, Geschichte und Rekonstruktion der Spessarter Glashütte Epstein I bei Kleinkahl," *Aschaffenburger Jahrbuch für Geschichte, Landeskunde und Kunst des Untermaingebietes* 28 (2010): 9–57; Peter Steppuhn and Ingrid Berg, *Glas aus dem Taunus. Glashandwerk von 1200 - 1700. Begleitpublikation zur Ausstellung in der Taunus-Galerie im Kreishaus des Hochtaunuskreises* (Bad Homburg v. d. Höhe: Hochtaunuskreis, Fachbereich Kultur, 2011); Peter Steppuhn, "Archäologie einer Glashüttenlandschaft – Der Hochtaunus," *Berichte der Kommission für Archäologische Landesforschung in Hessen (2006/2007)*, no. 9 (2009): 21–130.

[8] Sören Frommer and Aline Kottmann, *Die Glashütte Glaswasen im Schönbuch. Produktionsprozesse, Infrastruktur und Arbeitsalltag eines spätmittelalterlichen Betriebs*, 6th ed., Tübinger Forschungen zur historischen Archäologie, Bd.1 (Büchenbach: Faustus, 2004); Aline Kottmann, "Die Glashütte Glaswasen Mittelalterliche Glastechnologie im Schönbuch," in *Auf gläsernen Spuren. Der Beitrag Mitteleuropas zur archäologisch - historischen Glasforschung*, ed. Sabine von Felgenhauer-Schmiedt, Alexandrine Eibner, and Herbert Knittler, Beiträge zur Mittelalterarchäologie in Österreich 19 (Wien: Gesellschaft für Mittelalterarchäologie, 2003), 37–46.

[9] Hedvika Sedláčková, "Ninth- to Mid-16th-Century Glass Finds in Moravia," *Journal of Glass Studies* 48 (2006): 191–224; Hedvika Sedláčková and Dana Rohanová, *Renaissance and Baroque Glass from the Central Danube Region* (Brno: Karolinum, 2016); Eva Černá, Kateřina Tomková, and Václav Hulínský, "Proměny Skel Od 11. Do Konce 13. Století v Čechách. [The Glass Transformation in Bohemia between the Eleventh Century and the End of the Thirteenth Century]," *Archeologické Rozhledy*, no. LXVII (2015): 79–108; Eva Černá, *Stredověké Sklárny v Severozápadních Čechách : Přínos Archeologie k Dějinám Českého Sklářství*.

glassware found in different excavations across Vienna as well as glass workshop sites from the Roman Period to the nineteenth century in Austria. She not only summarized the glassmaking methods at the early modern workshop at Herrschaft Reichenau am Freiwald (Lower Austria), but also studied the glass findings.[10]

In Hungary a comprehensive work on all the known glass workshops from the Roman Period to the twentieth century was written by Gergely Csifféry in 2006.[11] However, the results of this book need re-evaluation. Little attention was paid to archaeological research and because new results have emerged since the publication of this volume as well.

Taking into account all aspects of glass production in medieval Hungary, other publications and research trends should also be emphasized. When it comes to medieval glassware and its in-depth analysis and reconstruction methods, the first name that comes to mind is Katalin H. Gyürky. She published two thorough glass catalogs concerning the glass finds from medieval Buda and excavations across Hungary. She wrote a number of articles on window glass, drawing reconstructions of glass vessels and glassmaking in general. [12] Another known archaeologist related to glass findings and glass workshops in Hungary is Edit Mester. She has created a catalog about the medieval glass finds from Visegrád. The book also contains a description of medieval glassmaking technology, a research summary of the Visegrád materials and integrates the report of the site at Diósjenő including the chemical analysis of the

[Mittelalterliche Glashütten in Nordwestböhmen : Beitrag Der Archäologie Zur Geschichte Des Böhmischen Glashüttenwesens] (Praha: Archeologický ústav AV ČR, 2016).

[10] Kinga Tarcsay, *Mittelalterliche und neuzeitliche Glasfunde aus Wien* (Wien: C&D Copy und Druck GesmbH, 1999); Kinga Tarcsay, *Frühneuzeitliche Glasproduktion in der Herrschaft Reichenau am Freiwald, Niederösterreich*, Fundbereichte aus Österreich Materialhefte 19 (Wien: Berger, 2008).

[11] Csifféry Gergely, *Magyarország üvegipara 1920-ig*, Studia Agriensia 25 (Eger: Mondat kft., 2006).

[12] Katalin H. Gyürky, *Üvegek a középkori Magyarországon [Glasses in the Middle Ages Hungary]* (Budapest: Budapesti Történeti Múzeum, 1991); Katalin H. Gyürky, "Glasimport und Glasherstellung im mittelalterlichen Ungarn," in *Auf gläsernen Spuren. Der Beitrag Mitteleuropas zir archäologisch - historischen Glasforschung*, ed. Sabine Felgenhauser-Schmiedt, Alexandrine Eibner, and Herbert Knittler, vol. 19, Beiträge zur Mittelalterarchäologie in Österreich (Wien: Österreichische Gesellschaft für Mittelalterarchäologie, 2003), 47–55; Katalin H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," *Communicationes Archaeologicae Hungariae*, 1989, 209–20; H. Gyürky Katalin, "The Use of Glass in Medieval Hungary," *Journal of Glass Studies* 28 (1986): 70–81; Katalin H. Gyürky, *Az üveg. Katalógus [The Glass - Catalog]*, Monumenta Historica Budapestinensia 5 (Budapest: Budapesti Történeti Múzeum, 1989), http://real-eod.mtak.hu/2934/1/09121.pdf.

glass finds. She also has published many complex studies on the excavated glass workshops in Hungary from the eleventh to eighteenth centuries.[13]

One general comment should be made concerning the main topic of this thesis. Unfortunately, only a few medieval glass workshops have been excavated to date. The earliest known medieval glass workshop was found in connection with the Benedictine monastery at

Pásztó by Ilona Valter.[14] Katalin H. Gyürky and Edit Mester led excavations several times in the woodlands of Börzsöny, near Diósjenő and unearthed three workshop sites located near to each other.[15] The most recent workshop complex was discovered at Visegrád- 5 Rév Street by Orsolya Mészáros and Mátyás Szőke. The unique workshop layout and furnaces were analyzed extensively by Orsolya Mészáros. She was also able to connect the excavated workshop to a written source, which makes it the first workshop site to have a written source as well as excavated features in Hungary.[16] Another unique site, Pomáz – Nagykovácsi puszta has already been researched in the twentieth century. More recently József Laszlovszky cleared up the misinterpretations about the site and continued the excavation and survey work. So far, the excavations have revealed a more complex settlement history than had been expected. It seems that the workshop complex operating in the buildings of a Cistercian grange, even placed

[13] Edit Mester, *Középkori üvegek [Medieval Glasses]*, Visegrád Régészeti Monográfiái 2 (Visegrád: MNM Mátyás király Múzeuma, 1997); Edit Mester, "Research of medieval glass vessels and glasshousdes in Hungary," in *Auf gläsernen Spuren. Der Beitrag Mitteleuropas zur archäologisch-historischen Glasforschung*, ed. Sabine Felgenhauser-Schmiedt, Alexandrine Eibner, and Herbert Knittler, vol. 19, Beiträge zur Mittelalterarchäologie in Österreich (Wien: Österreichische Gesellschaft für Mittelalterarchäologie, 2003), 55–75; Mester Edit, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," in *A középkor és kora-újkor régészete Magyarországon [Archaeology of the Middle Ages and the Early Modern Period in Hungary]*, ed. Kovács Gyöngyi and Benkő Elek, vol. 2, 2 vols. (Budapest: Magyar Tudományos Akadémia Régészeti Intézete, 2010), 643–74.

[14] Ilona Valter, *Pásztó a középkorban [Pásztó in the Middle Ages]* (Budapset: Metem, 2018).

[15] Katalin H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," *Archaeológiai Értesítő* 119 (1992): 69–85; Mester, *Középkori üvegek*; Edit Mester and István Szabó, "Research of Medieval Glass Vessels and Glasshouses in Visegrád and Diósjenő," in *Archaeometrical Research in Hungary II.*, ed. László Költő and László Bartosiewitz (Budapest-Kaposvár-Veszprém, 1998), 97–113.

[16] Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in *A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 675–99.

a furnace inside its abandoned chapel. [17] So far, these data represent the excavated environment while the landscape of production as well as the supply routes are yet to be revealed. Furthermore, these well-excavated sites can help us to contextualize the less well known production centers. Thus, individual data connected to workshops can be studied in the broader spatial context of all known glass production sites in medieval Hungary.

[17] József Laszlovszky and Karen Stark, "Medieval Glass Production at Pomáz-Nagykovácsi: The Finds and Heritage Interpretation of an Archeological Site," *Cultural Heritage Studies in Central Europe* 23 (2017): 239–64.

Chapter 1 - Use of Sources

Reconstructing medieval glassmaking methods based on various sources

Introduction

There are three types of sources that can help clarify the operation of medieval glass workshops. Written sources such as treatises describe the structure of the furnaces and glassmaking methods, while charters and itineraries can be used as evidence for the very existence of such workshops. However, these sources were written for a variety of purposes, often by people who may not have known anything about the practice of glassmaking. The second group covers visual sources. These images can be used to supplement written sources and represent a great comparative material. The third type of source includes archeological data and the results of experimental archeology.[18] Comprehensive research requires the use of all types of available sources to compare, complement, and contextualize the layout and the apparatus of a glass workshop or the methods of production. In this chapter, I shall explore the character and the limitations of the written and visual sources. By comparing them, I will reconstruct the process of glassmaking and the structures of glass workshops.

Written sources

The written sources regarding glass workshops can be separated into two main groups based on their function: treatises and charters. Most of the known medieval and early modern treatises come from Italian or German territories and they contain general descriptions about the way glass workshops should look like. They are very valuable texts for this research

[18]The archaeological sources will be discussed in detail in the later chapters.

because they describe workshops, often in a quite detailed way and they also focus on the technology used in these workshops. The limitation of this source type is that they mostly describe the manufacture of soda-lime-silica or natron glass, known as Venetian glass. This is problematic for the analysis because workshops in the Carpathian Basin had no access to sodium oxide (Na_2O).[19] Instead, they made their own alkali flux from potassium oxide (K_2O) called potash and they have produced the so-called forest glass.[20] This is an expressive phrase for this type of glass, because glassblowers needed the ash of potash-rich trees like beech and oak to obtain K_2O. The fundamental difference between the action of the two substances was that Venetian glass was transparent and clear. It remained well-preserved even after centuries. Forest glass, however, is usually greenish, its material contaminated with other elements, and survives poorly.[21] Despite differences in the material quality and form between the two kinds of glass, both needed the same temperatures to liquidize the mixture of ingredients and the masters made the same type of objects from the produced glass. It is therefore justifiable to assume that the furnaces in both regions were, to some extent, similar.

[19] The components of Venetian glass are 65-70% silica, 10-20% sodium oxide, and possibly calcium oxide. Silica melts over 1700°C, therefore ancient and medieval glassworkers had to use alkali fluxes to lower the melting point to 1200°C. In this case the flux came from a mineral called *trona* (containing Na_2O). This mineral was formed by evaporation and could be found near saline lakes such as those in Wadi el-Natrun in Egypt. Alternatively, the sodium may have come from the ashes of certain halophyte plants such as seaweed. These ingredients reached Venice by trading with Levant and Syria. David M. Jones, *Archaeological Evidence for Glassworking: Guidelines for Best Practice* (Bristol: English Heritage, 2011), 5–6; István Fórizs, "Üvegkészítés Magyarországon a kezdetektől a XVIII. századig" [Glassmaking in Hungary from the beginnings to the eighteenth century], *A Miskolci Egyetem Közleményei* 74 (2008): 115–16; For further reading and information about the topic, see: Ian C. Freestone and Mavis Bimson, "Early Venetian Enamelling on Glass: Technology and Origins," *Materials Issues in Art and Archaeology* 4 (1994): 417–19; Patrick W. McCray, *Glassmaking in Renaissance Venice: The Fragile Craft* (Aldershot: Ashgate, 1999); S. Cagno et al., "Study of Medieval Glass Fragments from Savona (Italy) and their Relation with the Glass Produced in Altare," *Journal of Archaeological Science* 30 (2012): 1–7.

[20] Forest glass (*Waldglas*) consisted of silica, potassium oxide and calcium oxide. To obtain alkali flux, the workshops burned certain type of woods for their potash-rich ash. Because of this process, the ash always contains other elements, so the resulting glass material is always contaminated with pebbles and bubbles. It has a naturally greenish color. Fórizs, "Üvegkészítés Magyarországon," 116.

[21] Due to the contamination in the glass material, the glass fragments usually lose their original color. This taphonomic process starts with the formation of a thin, iridescent layer, which slowly but constantly transform and eats away the surface, making the glass objects more fragile, soft, and crumby. This fragile layer tends to flake off and usually has a brownish, blackish, dull grey color which hides the original greenish color of forest glass. This color- and texture change is one of the reasons why it sometimes is difficult to recognize archeological glass findings. Jones, *Archaeological Evidence for Glassworking*, 4.

The treatises are too general and they typically illustrate foreign glass workshops. To date, there are no known treatises from Hungary, so only vague assumptions can be made about the similarities or differences between the workshops and methods. Fortunately, these suppositions can be supported or refuted by archaeological finds. While foreign treatises tend to be generic, to be used for comparison with the Hungarian archaeological material, the charters from the Kingdom of Hungary are both too specific and vague because they refer to a certain territory and focus on ownership without a description of the workshop. At the same time, since they contain different information, they can be used to complement the treatises. Local charters, for example, can be used to map out the locations of glass workshops in the Carpathian Basin but with the caveat that charter evidence can be misleading for dating workshops. The first mention of a workshop in a charter does not necessarily refer to the actual starting point of a settlement, building or workshop. For example, the glassmaking workshop in Teplice (Slovakia) was in operation for 200 years before the first charter reference to it in 1551.[22]

Medieval and early modern descriptions of glass production

The analysis of the treatises written by medieval or early modern authors requires a brief overview of their background and experience in glass production. The context of a source and the intentions of the authors must be considered as a complex issue in studying medieval glassmaking in Hungary based on foreign treatises.

The earliest known treatise is *De diversis artibus* written by Theophilus Presbyter around 1100-1120. There is an ongoing debate with vast secondary literature about his identity. Eckhard Freise identifies him with a Benedictine monk, Roger of Helmarshausen.[23] In his

[22] Katalin H. Gyürky, "The Use of Glass in Medieval Hungary," *Journal of Glass Studies* 28 (1986): 70.
[23] Eckhard Freise, "Roger von Helmarshausen in seiner monastischen Umwelt," *Frühmittelalterliche Studien* 15 (1981): 180–293; For more on the topic, see: Stefanos Kroustallis, "Theophilus Matters: The Thorny

work, he describes painting and metal works and the process of making stained window glass. The most accurate and large part of his description concerns the metalworks, while the chapter dealing with glass is the shortest and is sometimes unclear.[24] Even if he was not a glassblower himself, it is obvious that he had seen the process and consulted with the craftsmen.[25]

Unfortunately, after Theophilos Presbter there are no descriptions of glass production for centuries, although the thirteenth and fourteenth centuries were crucial for the emergence of glass workshops in Central Europe. It is only from the beginning of the sixteenth century that some relevant texts appear concerning manufacturing technology. Vannoccio Biringuccio (1480-1539) was an Italian metallurgist and alchemist who oversaw an iron mine near Sienna and later in charge of casting cannons for Venice and Florence. In his book, *De la pirotechnia* (1540), he describes and discusses metallurgy and mining practices. In connection with mines, he also offers a description of glassmaking from the perspective of an alchemist:

> I shall begin, then, by telling you, to the credit of the alchemists, how I believe that this thing was found through their desire to make gems; for when they could not bring them to perfection (as also happened with the metals) they made this beautiful and attractive product, glass.[26]

He used information from the *Historia naturalis* because he includes the story from Pliny the Elder concerning the discovery of glassmaking.[27] Meanwhile he has practical knowledge about

Question of the Authorship of the 'Schedula diversarum artium,'" in *Zwischen Kunsthandwerk und Kunst: Die* '*Schedula diversarum artium*', ed. Andreas Speer (Berlin / Boston: De Gruyer, 2000), 52–71; Ilya Dines, "The Theophilus Manuscript Tradition: Reconsidered in the Light of New Manuscript Discoveries," in *Zwischen Kunsthandwerk und Kunst*, 3–10.

[24] Presbyter Theophilus, *On Divers Arts: The Foremost Medieval Treatrise on Painting, Glassmaking and Metalwork,* trans. John G. Hawthorne and Cyril Stanley Smith (New York: Dover Publications, 1979): iii-v.

[25] "… I have made it my concern to hunt out this technique for your study as I learned it by looking and listening." Theophilus, *On Divers Arts*, 48.

[26] Vannoccio Biringuccio, *The Pirotechnia of Vannoccio Biringuccio: The Classic Sixteenth-Century Treatrise on Metal and Metallurgy*, trans. Cyril Stanley Smith and Martha Teach Gnudi (New York: Dover Publications, 1990), 126.

[27] Biringuccio, *The Pirotechnia*, 126–27.

glassmaking, not only because he was an alchemist, but because mines, and especially gold and silver mines, were closely connected to glass workshops because they needed glass vessels for the separation of gold from other metals.[28] Biringuccio also provides a practical guide to constructing furnaces and for the process of glassblowing.

Georgius Agricola (Georg Pawer, 1494-1555) was a German scholar who wrote *De re metallica libri XII* (1556*),* a systematic study of metallurgy and mining. He lived and worked as a town physician and pharmacist in the mining town of Joachimsthal (Jáchimov, Bohemia) and later moved to another mining town, Chemnitz in Saxony. Beside his practical knowledge, he also used sources such as Pliny the Elder and was influenced greatly by Biringuccio's work which he translated from Italian to Latin.[29]

Antonio Neri (1576-1614) was working alongside Venetian glassmakers who had relocated their workshops to Pisa and Antwerp. He gathered work experience in Florence under the patronage of Don Antonio de' Medici to whom he dedicated his book: *L'Arte vetraria* (1612). In *The Art of Glass* he collected all the useful recipes for glass and techniques for glassmaking based on his experiments in chapter 133. He even shared his experiments and their results with the readers. In the book, he emphasizes the importance of the geographical location of the different elements needed to produce different types and colored glass. The book gained more recognition after its first English translation by Christopher Merret in 1662. Merret was an English physician, botanist and librarian who not only translated but added a useful commentary to the work.[30]

[28]For the separation of gold, they used the *aqua regia* (king's water), a mixture of nitric acid and hydrochloric acid, which dissolves all metals except gold. Csiffáry Gergely, *Magyarország üvegipara 1920-ig*, Studia Agriensia 25 (Eger: Mondat, 2006), 83–84.

[29] Georgius Agricola, *De re metallica*, trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), x-xv.

[30] Diane Dolbashian, "Antonio Neri, L' Arte Vetraria, 1612," Corning Museum of Glass, June 24, 2013, https://www.cmog.org/article/antonio-neri-l-arte-vetraria-1612.

The most relevant source for this thesis (so far) is Guasparre di Simone Parigini's practical plan for establishing a glass workshop in Mugello (1481).[31] This source contains information on the structure of an entire workshop, the ingredients and even the furniture and food supply for the glassmakers. These operational aspects are important for analyzing the methods and structure of a workshop and for the operation processes at a workshop site. The purpose and impact of the text is unknown. Orsolya Mészáros suggests that the manual was produced for the Medici family when they planned to establish a glass workshop and needed an experienced master's opinion concerned the ratio of return on investment.[32]

Visual Sources

Pictures depicting the process of glassmaking help to fill some of the gaps left by the surviving written sources. Although the most often quoted and reproduced work of Agricola's *De re metallica* contains pictures of the kilns and tools, it is also instructive to see other examples from different places and centuries.[33] These pictures can be found in manuscripts, paintings, glass objects or even engraved on animal bones.

One of the most famous depictions of glassmaking is the illustration from *The travels of Sir John Mandeville* (Figure 1).[34] This color image is very important, as it shows the whole setting of a workshop, with the different phases of the production process. Although the text of the manuscript is connected to the travels of an Englishman, this particular miniature has been

[31] Archivio di Stato, Firenze. Miscellanea Medicea. Vol. 27. I'. III. Fol. 1001r-1005v. Translated and analyzed by Orsolya Mészáros. See Orsolya Mészáros, "Egy 15. századi toszkán üvegműhely [Eine toskanische Glaswerkstatt aus dem 15. Jahrhundert]," *Folia Archeologica* 52 (2006 2005) 221-247.

[32]Orsolya Mészáros, "Egy 15. századi toszkán üvegműhely [Eine toskanische Glaswerkstatt aus dem 15. Jahrhundert]," *Folia Archeologica* 52 (2006 2005): 221–22.

[33]Agricola, *De re metallica*, 588–89.

[34] The British Library Board MS (Add 24189, f16). See also: R.J. Charleston, "Vessel Glass," in *English Medieval Industries. Craftsmen, Techniques, Products*, ed. John Blair and Nigel Ramsay (London: Hambledon Press, 1991), 239 Fig.109; Chris Welch, *Medieval and Early Post-Medieval Glassworks: Introductions to Heritage Assets*, ed. Joe Flatman and Pete Herring, Historic England (Swindon: English Heritage, 2018) frontpage.

discussed in the context of Bohemia, so it may be even more relevant for the discussion of the Central European situation. The picture shows how the glassworker extracts sand from a sandpit in the background while another assistant carries it to the furnace. By the furnace, a craftsman gathers glass onto a blowpipe, while a second master shapes a blown glass bubble on a marble slab. While one of the masters stokes the fire, another worker places the ready vessels into an annealing furnace. On the left side of the picture, a craftsman or the magister inspect the finished products. On the right side and above the furnace, there are two sheds; one to protect the kilns while the other functions as a storage place for drying timber.

One of the relevant images comes from the beautifully illustrated *Tractatus de herbis* (1440).[35] The book was designed for physicians and pharmacists to help them identify plants. Interestingly, one of the folios depicts an angular furnace, with an elevated hearth and a workplace on the upper part with small openings on the side (Figure 2). One worker is blowing a glass object, using a marble block to shape the vessel. Meanwhile, other workers are taking care of the crucibles and pre-heating the blowing pipes.

Another *Tractatus de herbis*, attributed to Pedanius Dioscorides (1458), contains a similar image (Figure 3).[36] The picture shows a rectangular-shaped furnace. Orsolya Mészáros interprets this structure as a glass furnace, but it can be also interpreted as an annealing furnace.[37] In her explanation, one of the workers put a glass-vessel in the furnace while according to the other interpretation one of the masters is placing the finished products in the kiln. While the other one sits while blowing a pointed beaker (*Nuppenbecher*). The troubling aspect of the latter version is that the first workman is shown separating the finished glass objects from the pontil with his bare hands. This would of course cause him serious burn

[35] "Tractatus de Herbis" (illustrated treatise, Italy, N. (Lombardy), c 1440), fol. 101.v, Sloane 4016, Brithis Library, https://www.bl.uk/catalogues/illuminatedmanuscripts/record.asp?MSID=7796.

[36] Daniela Stiaffini, *II vetro nel medioevo: Tecniche, strutture, manufatti*, Tardoantico e Medioevo (Rome: F.lli Palombi, 1999), 53.

[37] Mészáros, "Egy 15. századi toszkán üvegműhely," 236.

injuries because at this stage the temperature of the glass is over 600 °C. However, I find the second explanation more reasonable, not just because the actions but the clothes of the two depicted characters are out of the place. They wear fashionable clothes with pointy-shoes more like the Nobility would wear as opposed to the loose fitting clothing of craftsmen. This suggests that the picture possibly shows how not to make glass, thus, it should not be taken as an entirely accurate depiction of a glass workshop. At closer inspection, even the furnace apertures are depicted differently compared to the description of Agricola and Theophilus concerning the glass furnace.[38] Figure 3 shows a furnace with three or more openings to the fire-box, while in the upper chamber only one trumpet-shaped aperture is visible, similarly to the description of an annealing furnace from Biringuccio's *De la pirotechnia*.[39]

The text of Vannoccio Biringuccio's book from 1540 has already been presented in the part on written sources, but the illustration of the text is also an important source (Figure 4). It shows a glass furnace with four visible ribs supporting the vault. The kiln has one arched opening to the fire-box. For the upper chamber, two big rectangular apertures are visible together with the small stone or marble shelves used to help gather the liquified glass material together and then put on the blowpipe. Next to these apertures there are also two small oval openings used to preheat the iron tools. This furnace also functioned as an annealing kiln, because there is another chamber with two visible openings on the top. The palm-sized opening in the middle from the hearth is also typical of an annealing furnace chamber in Agricola's work.[40] Five craftsmen are shown sitting and working around the furnace. Their number suggests there were four apertures used for glassblowing, despite the picture showing only two apertures. While the masters shape and blow glass close to the openings, one of the workers brings firewood to stoke the fire. In the right corner, the chief glass master or magister is stands

[38] Theophilus, *On Divers Arts*, 50–51; Agricola, *De Re Metallica*, 1950, 587.
[39] Biringuccio, *De La Pirotechnia*, 128.
[40] Agricola, *De Re Metallica*, 1950, 589.

on a bench and supervises the work or possibly inspects the finished products. His higher status in the workshop is indicated by his different, fashionable clothes and hat.

Early modern treatises such as *De re metallica (1556)* contain several pictures about the different type of glass furnaces and the tools used during the process of glassmaking. This book has more detailed pictures than Biringuccio's work and is therefore a very important source for the interpretation of various types of furnaces. An ovoid melting furnace can be seen on this picture (Figure 5). In front of the furnace, a worker breaks a big chunk of molten glass into smaller pieces before the second heating. The furnace is two chambered; the lower chamber is the fire-box, which has an arched opening. The upper chamber has only one visible aperture in which to place in the mixed ingredients for melting.

In his book, Agricola describes two different workshop structures. In the first one, the craftsmen use three separately constructed furnaces, while in the second type of workshop they use only two furnaces: one for melting the ingredients together while in this case the other glass furnace has another chamber for gradually cooling down the finished products. The first version is depicted on the next picture (Figure 6). The ovoid glass furnace with two chambers has one aperture connecting to the fire-box or hearth. The upper chamber has four visible, arched openings.

This glass furnace is built together with a rectangular annealing furnace. It also has two chambers although the top chamber has only one visible window. In the front, three bellied crucibles are depicted. Next to them are two oblong receptacles used for cooling down the finished products in the annealing furnace.

Figure 7 also comes from the *De re metallica* and it depicts an ovoid glass furnace, with four small openings in the second chamber of the kiln. One of the workers on the right gathers parison, while the other four craftsmen are shown blowing and shaping glass objects. On the

left, near the furnace, there is a pile of wood drying and waiting to be used. A pair of tools can be seen hanging from a nail on the wall of the furnace. A few blowpipes and molds are shown in the middle of the picture. In the front, there are fragments of broken glass and waste products waiting to be recycled in the next melting. At the front, there is a wooden storage box containing finished glass products, while one of the masters inspects them.

The next picture from Agricola's book (Figure 8) shows the second version of the described workshop structures, in which the glass- and the annealing furnace are built together. Both depicted furnaces have three chambers. The lowest ones are the hearths with one arched opening to stoke the fire. The middle chamber has four visible apertures used for glass re-melting and gathering. The top chamber was used as an annealing furnace with only one arched opening. The depicted furnace in the back shows the inner structure of the kiln. This depiction indicates that the second chamber has a shelf for the crucibles and the top chamber has a small rectangular opening connecting to the other chambers.

Paintings, such as that of Francesco I on a visit to his glassworks by Mannerist Italian painter Giovanni Maria Butteri, provide another corpus of visual sources (Figure 9). The accuracy of the image suggests that Butteri had a chance to visit the workshop of a Venetian glassmaker, Bortolo, who set up his own glassworks in Florence in 1569. On the right, there is a furnace under construction and in the background an ovoid glass furnace is in operation, surrounded by five or six glassblowers.[41]

Compared with the written sources, images of glassworks provide spatial contexts for the workshops. They provide information about how space was used as well as the tools and vessels used and the structure of the furnaces. The above examples show the various types of

[41] Marco Beretta, "Material and Temporal Powers at the Casino Di San Marco (1574-1621)," in *Laboratories of Art: Alchemy and Art Technology from Antiquity to the eighteenth century*, ed. Sven Durpé (Switzerland: Springer International Publishing, 2014), 137–38.

sources that can contain images.[42] Each image has its won context and function. Similarly to the written sources, none of the images comes from the territory of the Kingdom of Hungary so any conclusions that can be drawn are necessarily limited and must be complemented by written sources and archeological evidence.

The needs of a glass workshop and the duties of the craftsmen

The best way to understand manufacturing procedures in a glass workshop through the written sources is to analyze the required structure of its buildings and the hints about the life and work of the craftsmen. Parigini suggests that a workshop needs at least three rooms in a family house, with a separated section for living, cooking and sleeping.[43] The workspace and the furnaces are best situated on the ground floor of the building or attached to it as a separate part, which is 7x11.6 m in size. In this space, there should be different types of furnaces and a shed or roof above the furnaces for protection as well as for stocking the billets of timber and drying them out.[44] For a furnace to operate well, eight masters and three apprentices are necessary. Parigini states that the masters need a separate section in the house for living, with two comfortable and big beds, and sheets changed every fifteen days.[45] The plan for the glass workshop in Mugello also prescribes the amount of bread and of white and red wine that the masters and the apprentices should be supplied with. But more importantly, he describes all of the chores that the craftsmen must carry out in hierarchical order (Figure 10).[46] On top of this

[42] For further reading on the topic of depictions of glass workshops, see Orsolya Mészáros, "A középkori üvegkészítés fémeszközei [The Metal Tools of the Medieval Glassmaking]," in *Hadi és más nevezetes történetek. Tanulmányok Veszprémy László tiszteletére*, ed. Katalin Mária Kincses (Budapest: HM Hadtörténeti Intézet és Múzeum, 2018), 353–56; McCray, *Glassmaking in Renaissance Venice: The Fragile Craft*; Stiaffini, *II vetro nel medioevo: Tecniche, strutture, manufatti*; Mészáros, "Egy 15. századi toszkán üvegműhely," 232–43.

[43] Mészáros, "Egy 15. századi toszkán üvegműhely," 223.

[44] Mészáros, 226.

[45] Mészáros, 222, 226.

[46] The number of the craftsmen must have varied according to its region, the century it was functioning and the purpose of the workshop.

hierarchy, stands a magister, who works for the owner or chief master, who owns the workshop. His duty is to manage the trading and oversee getting the needed supplies. The chief glassblower master's job is to blow 300 jugs daily and create the more advanced decorations for the other glass objects too. The conciatore glass master takes care of the furnace and prepares raw materials while producing 100 flasks daily. According to Parigini, there should be six other glassblowers, who blow together 3000 beakers daily. And finally, there should be three apprentices who prepare and melt the glass in the calcare while helping out the masters in all their tasks.[47] In addition, Parigini's plan recommends that the workshop has a storage building with wooden shelves constructed near the annealing furnaces to store all the finished products. A well, river, lake or other source of water is necessary adjacent to the melting- and glass furnaces, because they use cold water to cool the iron tools and molds.[48] Parigini also emphasizes that there should be a blacksmith operating in the close vicinity, because the iron tools usually need repair every day.[49]

Fire resistant clay and crucibles for glassmaking

In addition to the ingredients for glassmaking and the great amount of firewood needed to stoke the furnaces, the other most important raw material for glassmaking is fire-resistant clay for making bricks and glass vessels. For the purpose of fire-resistance, Theophilus Presbyter suggests the use of a white pottery clay: *"... dry it out, grind it carefully, pour water on it, knead it hard with a piece of wood and make your pots."*[50] This rare, fire-resistant clay could come from a distance to the glass workshop. There is evidence from sixteenth-seventeenth century England that the best fire-cay was regularly transported from

[47] Mészáros, "Egy 15. századi toszkán üvegműhely," 229.
[48] "There have to be a well in the named place, because of the high demand for water." Mészáros, 226.
[49] Mészáros, 227.
[50] Theophilus, *On Divers Arts*, 53–54.

Worcestershire to the workshops.[51] Theophilus writes that this clay was used for building the furnaces and making crucibles as well.[52] The clay should be well washed and clean, without air-bubbles for these purposes.[53] According to Vannoccio Biringuccio, the pots were made on a wheel although archeological evidence from England and Hungary shows that the crucibles made from built up of rolls of clay.[54] Theophilus in his book only provides a vague description of the glass melting pots: "These should be wide at the top, narrowing at the bottom, and should have a small in-curving lip around their rims."[55] These were made probably for a specific reason or rather these were the pots used in the twelfth century. Because the Mandeville miniature (Figure 1) shows crucibles which were more bucket-shaped or had everted sides with an out-turned lip.[56] In Agricola's *De re metallica,* the pots are described as bellied vessels, and they are almost the same size as those shown in Biringuccio's work (Table 1).[57] In his commentary, Christopher Merrett emphasizes that there were small round-based crucibles serving other special purposes such as colored glassmaking.[58] But Agricola is the only author who describes oblong, earthenware receptacles, used in the annealing furnace.[59] Parigini only writes about the different size and shape crucibles for glass melting. He suggests that a workshop needs more spare pots, because they break frequently due to the great fluctuations in temperature in the glass manufacturing process.[60] Due to this situation, it is possible that glass

[51] Charleston, "Vessel Glass," 240.
[52] Theophilus, *On Divers Arts,* 49, 52.
[53] Antonio Neri, *The Art of Glass: Wherein Are Shown the Wayes to Make and Colour Glass, Pastes, Enamels, Lakes and Other Curiosities*, trans. Christopher Merrett (London: Printed by A.W. for O. Pulleyn, 1662), 245–46,
[54] Biringuccio, *De La Pirotechnia*, 128; Charleston, "Vesel Glass," 240; József Laszlovszky and Karen Stark, "Medieval Glass Production at Pomáz-Nagykovácsi: The Finds and Heritage Interpretation of an Archeological Site," *Cultural Heritage Studies in Central Europe* 23 (2017): 249.
[55] Theophilus, *On Divers Arts,* 53.
[56] Charleston, "Vessel Glass," 241.
[57] Agricola, *De Re Metallica,* 1950, 587; Biringuccio, *De La Pirotechnia,* 129.
[58] Neri, *The Art of Glass,* 246.
[59] Agricola, *De Re Metallica,* 1950, 589.
[60] Mészáros, "Egy 15. századi toszkán üvegműhely," 227.

workshops must have had strong ties with nearby pottery workshops or, presumably, a craftman who also worked as a potter.[61]

Iron tools for glassmaking

Iron tools are just as important as the fire-resistant pots in the process of glassmaking. They have different shapes, sizes and types purposes. These tools are rarely found archaeologically, because of their high value and good quality. Furthermore, iron objects could basically be recycled in preindustrial periods to manufacture new tools or objects. Even if they were lost or left at the site of the workshop for whatever reason, corrosion later transformed them, so it becomes very difficult to identify what they were originally. Therefore, in this chapter I will only summarize the main tools used for glassblowing, mentioned and depicted in the written sources.

Among all the iron tools the blowpipe was the most important one for glassmaking (Figures. 11 and 12).[62] It consisted of two parts: a long iron tube and the other a wooden part making it possible to hold the hot iron tool. The blowpipes are visible in almost every picture which shows a functionating furnace (Figures 1, 2, 3,4, 7, 9). In their books, Vannoccio Biringuccio and Georgius Agricola describe the blowpipes as being narrow, cc. 80-100 cm, tubes.[63] In Parigini's workshop plan, the blowpipe was the most expensive and yet the most needed iron tool. Parigini even suggests that the owner should buy used ones to save money, because the workshop required 20 of them.[64]

[61] Charleston, "Vessel Glass," 241.

[62] It has several name in different sources: pfeife, felle, pipe, pipa, canna da soffio, canna di ferro Mészáros, "A középkori üvegkészítés fémeszközei," 346.

[63] Biringuccio, *De La Pirotechnia*, 127; Agricola, *De Re Metallica*, 1950, 592; Mészáros, "A középkori üvegkészítés fémeszközei," 346.

[64] Mészáros, "Egy 15. századi toszkán üvegműhely," 227.

The pontil also played an important role in shaping and moving the glass objects.[65] It is a long and solid, thin iron rod. The pontil was used to help shape an object during blowing. The masters also moved the finished products to the annealing furnace with the help of this simple iron tool.[66] According to Parigini, a fully equipped workshop must possess 14 pontils.[67]

Tweezers, tongs and pliers were used to shape and decorate. They came in different sizes and forms (Figures 11-12), each of them with a different purpose.[68] Parigini writes about 12 tweezers and 3 tongs.[69] The craftsmen also used molds made out of bronze for shaping purposes although cheaper versions could be made out of wood too.[70]

Furnaces

The most important part of the workshop was the furnace where the magic of glassmaking happens. Three types of furnaces were necessary in the manufacturing process: melting-, glass- and annealing furnaces. Some were constructed together in various ways, some were built separately from each other.[71] All of the furnaces were constructed from fire and heat-resistant bricks, rocks and clay.[72]

The purpose of the melting or fritting furnace (Parigini = *calcare*, Biringuccio= *forno di reverbero*, Neri= *calcaria*) was to melt a proper mixture of ingredients together. This type of furnace is usually described as a rectangular or ovoid furnace.[73] The hearth or fire-box was

[65] This tool also has different names: hefteisen (German), punty (English), puntello (Italian), köldökvas (Hungarian), vaspálca (Hungarian), ragadóvas (Hungarian)

[66] Mészáros, "A középkori üvegkészítés fémeszközei," 347.

[67] Mészáros, "Egy 15. századi toszkán üvegműhely," 227.

[68] Mészáros, "A középkori üvegkészítés fémeszközei," 348.

[69] Mészáros, "Egy 15. századi toszkán üvegműhely," 227.

[70] Mészáros, "A középkori üvegkészítés fémeszközei," 349.

[71] Peter Kurzmann, *Mittelalterliche Glastechnologie: Archäologie - Schriftquellen - Archäochemie - Experimente* (Frankfurt am Main: Peter Lang, 2004), 69–101.

[72] Theophilus, *On Divers Arts*, 49; Charleston, "Vessel Glass," 245.

[73] Theophilus, *On Divers Arts*, 49–51; Agricola, *De Re Metallica*, 587-88. In this aspect there is a contradiction between Agricola's description and the pictures in De re metallica. He writes about a rectangular furnace, meanwhile in the book there is only one melting furnace, which is oval shaped. (Fig.5)

located in the lower chamber and the workspace in the upper chamber. A fire-trench lower chamber ran through the long axis of the furnace. The upper chamber had only one arched opening, supported with stones. The ingredients were heated up in this furnace to 1000-1200°C and evenly melted together while being stirred continuously. After the workers removed the material, it cooled down and become *fritta* as Biringuccio called it or *vetro cotto* (boiled glass) as Paragini named it.[74] This work stage did not utilize the glass-pots. These crucibles were only used for reheating the vitreous material according to Theophilus.[75] Even though Agricola explains that the crucibles were only pre-heated here, without the parison.[76] Both Biringuccio and Agricola suggest that the glassy material was kept separate from the flames of the kiln necessitating two chambers. When the fire-box was separate, the smoke had to escape through the opening on the hearth's wall, while the hole on the top of the furnace was simply there to let out the hot air.[77] The measurements of the rectangular melting furnaces are almost the same in Biringuccio's and Agricola's work (Table 2) The length of the kiln is roughly 2 m, the width is about 1 m 30 cm and the height of their upper chamber is 60-70 cm. However, the melting furnace's height and width described by Theophilus is much larger than the sizes mentioned by the latter authors. The height of his furnace is about 1m 20 cm which can be explained by the fact that he counted the two chambers' heights together. However, this does not explain why the width of his furnace, according to him, is about 3 m, which is more than double the measurements recommended by the first two authors.

The glass furnace (*fornace*) usually had an ovoid or rectangular shape. The ovoid shape however, seems to have been more common. Both Agricola and Biringuccio describe an ovoid

[74] Biringuccio, *De La Pirotechnia*, 128; Mészáros, "Egy 15. századi toszkán üvegműhely," 223; Antonio Neri makes a difference between *fritta ordinaria*, which is a less clear, ordinary material and the *fritta di cristallo* which is a clearer glass material. Neri, *The Art of Glass*, 9-10.

[75] Theophilus, *On Divers Arts*, 49–50.

[76] Agricola, *De Re Metallica*, 1950, 588.

[77] Agricola, *De re metallica*, 587-88; Biringuccio, *De la pirotechnia*, 128–29; Mészáros, "Egy 15. századi toszkán üvegműhely," 234; Theophilus, *On Divers Arts*, 49.

furnace while Theophilus writes about a rectangular glass furnace.[78] If the kiln was separately built from the annealing furnace, it had two chambers. The lower one held the hearth with a fire-trench, and one or two openings, while the upper chamber workspace consisted of a strong shelf to hold the crucibles which was about 2/3 braccio (cc.46 cm) wide according to Biringuccio.[79] The ovoid furnaces had five or six small outer arches that supported the vault with small arched openings under them. The purpose of this kiln was to reheat the glass material (*fritta*) in crucibles from the melting furnaces and to provide access to the liquid glass during the process of glassblowing. The upper chamber therefore had 4-8 apertures about 50 cm in height. These apertures even had a berm made of stone or fire-resistant clay.[80] The four openings seems to have been more common in earlier, smaller furnaces such as those described by Parigini or seen on the Mandeville miniature (Figure1.).[81] In their early modern treatises, Agricola and Biringuccio write about 8 openings although on the pictures in their books only four are visible (Figures 4, 6, 8).[82] According to Agricola, during heating, the apertures were temporary walled up with clay, the workers only leaving a small hole where they could pre-heat iron tools such as a blowpipe or pontil and through which they could inspect the glass material.[83] The measurements of the glass kiln (Table 1) compared to the melting furnace in the books of Agricola and Biringuccio display a ratio of 1.5 -2 ratio in favor of the glass furnaces.[84] However, in Theophilus's description, the glass furnace seems exceptionally large with its 8 openings, a high number for twelfth century glass workshops.[85] Based on his

[78] Agricola, *De Re Metallica*, 1950, 589; Biringuccio, *De La Pirotechnia*, 127–28; Theophilus, *On Divers Arts*, 49–50.

[79] Biringuccio, *De La Pirotechnia*, 129.

[80] Mészáros, "Egy 15. századi toszkán üvegműhely," 237.

[81] Mészáros, 226; Charleston, "Vessel Glass," 246–47.

[82] Biringuccio, *De La Pirotechnia*, 128–29; Mészáros, "Egy 15. századi toszkán üvegműhely," 227; Agricola, *De Re Metallica*, 1950, 587.

[83] Agricola, *De Re Metallica*, 1950, 587.

[84] Biringuccio, *De La Pirotechnia*, 127–28; Agricola, *De Re Metallica*, 1950, 576–87; Mészáros, "Egy 15. századi toszkán üvegműhely," 239.

[85] Charleston, "Vessel Glass," 247; Theophilus, *On Divers Arts*, 49–51.

calculations R. J. Charleston thoroughly argues that the furnace described by Theophilus should have only four openings for four crucibles.[86]

The purpose of the annealing furnaces (*fornetti*) was to gradually cool down the finished glass products. The annealing kilns were sometimes built separately in a rectangular shape as in the descriptions of Theophilus, and Agricola. Sometimes they were built as a third chamber in the glass kilns as shown in the works of Biringuccio and Agricola.[87] While in Parigini's workshop plan there are several small annealing furnaces, their structure and form are unclear.[88] The separately built rectangular annealing furnaces had two chambers: the lower one had one opening connecting to the fire-box while the upper one also had one or two trumpet-shaped apertures according to Biringuccio.[89] After finishing the glass products, the masters put the objects into the furnace with the help of a pontil or blowpipe. Only one author writes about a special earthenware receptacle to contain the finished products in bundles which the glassblowers put into the annealing furnace. This method seems easier and a faster way to handle the finished products.[90]

The built-together version of the annealing furnace had a different structure. It functioned as the third chamber of the glass furnace. The place for cooling down the objects was smaller than in the earlier version, and the height of this chamber was about 1m 40 cm (Table 1). It had one or two openings on the side. In the middle of this chamber's floor there was an oval or rectangular palm-sized opening (7.5 cm).[91] The different types are even depicted in Figure 4 and Figure 8. This elevated level was too high (cc. 2 m 80 cm) to reach and to safely put the product in the kiln, however. Because of this, the glassworkers built a scaffolding or

[86] Charleston, "Vessel Glass," 246–47.
[87] Theophilus, *On Divers Arts*, 51–52; Agricola, *De Re Metallica*, 1950, 589; Biringuccio, *De La Pirotechnia*, 128–29.
[88] Mészáros, "Egy 15. századi toszkán üvegműhely," 226.
[89] Biringuccio, *De La Pirotechnia*, 128; Mészáros, "Egy 15. századi toszkán üvegműhely," 238.
[90] Agricola, *De Re Metallica*, 1950, 592.
[91] Agricola, 592; Biringuccio, *De La Pirotechnia*, 128.

bench to help them reach the openings. This stand is visible on Figure 4 and Agricola writes about this practice in *De re metallica*.[92]

Treatise writers usually supply the reader with the measurements of the furnaces according to their type. This data in Table 1 can be immensely useful for the identification of their archaeological remains. For example, in Agricola and Biringuccio, the glass kilns tend to be twice the size of melting kilns regardless of the shape of the furnaces.[93] The written explanations and the pictures also play a crucial role in understanding the function of the different types of furnaces.

The glassmaking manufacturing process

Once the necessary amounts of raw materials were collected and the melting furnace was prepared, the glassworkers put the mixed ingredients in the furnace and melted them together (Figure 13). The first boiling required 8 hours but after the melting furnace reached the needed temperature, the transformation process took another 5 hours.[94] The workers and the master *conciatore* had maintain the fire and ensure that the melting mixture was continuously stirred. After finishing with one portion, they pulled out the glassy material and put in another round of the mixed, raw ingredients. Later, when the glassy material solidified and gradually cooled down, they chopped it into usable and transportable chunks (*frittas*). Then, for glass blowing, they reheated the *frittas* in the crucibles using either the melting furnace or the glass furnace.[95] Once the frit turned into a clear liquid, the glassblowers placed a small amount of glass (a gather) on the end of their pre-heated pipes and started to blow and

[92] Agricola, *De Re Metallica*, 1950, 592.
[93] Biringuccio, *De la pirotechnia*, 128–29; Agricola, *De re metallica*, 586–89.
[94] Mészáros, "Egy 15. századi toszkán üvegműhely," 228.
[95] Biringuccio, *De la Pirotechnia*, 127–28; Theophilus, *On Divers Arts*, 54–55.

form the vessels or window glasses.[96] Glass blowers also used wooden or bronze molds, iron tools and marble slabs to form the glass objects.[97] During the shaping and blowing, the masters could sit on stools as in Figures 2, 3, 4 and, 9 or stood as in Figures 1 and 7. During blowing, Parigini and Biringuccio warn the masters that they should move the blowpipe away from their mouth when they breath out, to avoid "breathing in fire".[98] When they finished blowing and decorating the glass object, they attached a pre-heated pontil to the bottom with the help of a small amount of glass. After the pontil was attached, the blowpipe was cut off from the upper part and the mouth of the vessel was formed. This finished product had to be quickly placed in the annealing furnace to avoid shattering or cracking due to sudden, sharp drops in temperature. The finished products were cooled gradually in the annealing furnace.[99]

Conclusion

The examination of the written and visual sources showed that glassmaking in the Middle Ages was a difficult and complicated task, connected to and even depending on several other crafts. This comparison was also useful to help me understand how the different type of sources could be understood and complement each other.

The main purpose of this chapter was to reconstruct the needs, the contexts and the working methods found in medieval glass workshops. A functioning workshop needed a house for the workers and a workspace which contained the two or three different furnaces as well as a shed for drying firewood. A storage building is also required for the finished products. At the same time, a workshop also needs to insure a continuous supply of raw ingredients, water, timber, fire-resistant clay or pottery and iron tools from the nearest blacksmith (Figure 14).

[96] Agricola, *De re metallica*, 592; Mészáros, "Eine toskanische Glaswerkstatt," 229.
[97] Mészáros, "A középkori üvegkészítés fémeszközei" [The metal tools of medieval glassmaking], 349.
[98] Biringuccio, *De La Pirotechnia*, 129.
[99] Agricola, *De Re Metallica*, 1950, 592; Biringuccio, *De La Pirotechnia*, 129.

These connections and needs will play crucial roles in the analysis of the environmental and economic needs of medieval glass workshops in the Kingdom of Hungary. It is also important to note that these texts and the images were produced in different periods and probably also reflect different production technologies to some extent. Therefore, in the analysis of the archaeological remains of medieval and early modern workshops from Hungary they should be treated as possible models for reconstructing the workshops and the technologies but not as direct evidence for any structural details or as simple explanations for all aspects of glassblowing that are brought to light at these production sites.

Chapter 2 – The problems of identifying glass workshops

Introduction

In light of the analysis of the written and visual sources in chapter 1, I will investigate the archaeological indicators marking the presence of glassmaking at archaeological sites. The chapter begins with a short evaluation of the different data, collected from various types of sources. In the next part of this chapter, I will identify the most reliable markers of glassmaking at archaeological sites. After this analysis and the identification of these indicators, the chapter offers an overview of the known medieval glass workshops from the Kingdom of Hungary. In this context, previous literature has concentrated on describing and identifying glass workshops, even though the evidence for their existence was inadequate.[100] A critical re-evaluation of these sites is therefore essential in this part of the present study. Substantial work has been carried out on collecting these medieval and early modern glass workshops by Gergely Csifféry and Edit Mester.[101] However, little work has been done on the problem of whether are these sites really had functioning glass workshops on them or whether the evidence used to identify their presence was insufficient or not to really confirm their existence.

Indicators of a glass workshop

In ideal circumstances, all the different types of sources would be available for the same site. The information they contain about the past is complementary and overlapping at the same time. With written sources, one can establish the dating of the workshop and other aspects such

[100] For the previous scholarly literature see: Gergely Csifféry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," *Agria*, Az Egri Múzeum Évkönyve - Annales Musei Agriensis, 33 (1997): 125–49; Csifféry, *Magyarország üvegipara 1920-ig*.

[101] Csifféry, *Magyarország üvegipara 1920-ig*; Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]."

as trade and market issues. The social context could even be interpreted and understood. Non-destructive archaeological methods, surveys, and excavations can provide more information on the material and environmental contexts of the workshops. In the best-case scenario, archaeological surveys can produce information about the site from the *in situ* remains, workshop waste, raw materials, building materials, tools and finished products (Figure15) Unfortunately, in the vast majority of cases, the finds comprise broken glass, glass slag, fragments of crucibles and fire-resistant bricks. However, a few pieces of glass slags or broken glass may be insufficient to convincingly prove the presence of a medieval glass workshop. For instance, glass slag alone can be found in excavated sites of castles, settlements etc. in connection with conflagrations. Therefore, a complex set of criteria should be established for the identification of workshops, based on all possible source types.

Overview of the glass workshops in the written sources

Charters and account books may contain evidence concerning an existing glass workshop, by naming the nearest settlement. Unfortunately, the localization of the glass workshops based only on the written sources is virtually impossible. Also, these documents do not usually contain information about the layout and the structures of the workshop or of the furnaces. They can, however, provide more detailed pieces of information about the glassblowers, the finished products, the trading, the needed supplies and the proprietorship.

Most of the written sources are connected to mining towns because the goldmines needed glass objects to hold the *aqua regia,* which was an acid used for the separation of gold from other metals. The urban administration and the importance of these mining towns also generated a significant number of written sources. Furthermore, the documentary evidence from the northern part of the kingdom has survived in significant numbers because this part of

the kingdom was not devastated by the wars of the Ottoman period in the sixteenth and seventeenth centuries. The earliest charter is about the glass workshop at Sklenó Teplice, which was active from the 1330 to the end of the sixteenth century and provided glass for royal mining towns like Kremnica as well as for near by Šášov Castle.[102] Another glass workshop was established in 1360 by Peter Glaser in Sklené close to this other workshop. This glass workshop also produced glass for Kremnica. The workshop received its wood supplies from Badínsky prales.[103] Banská Bystrica and Banská Štiavnica also had glass workshops producing merchandise connected to their gold mining and minting activities.[104]

Other charter evidence touch on glass workshops by describing the legal issues and litigations connected to them. For example,Antonius Italicus, a glassmake who had a workshop in Felhévíz near Buda, took the water mill of the Poor Clares of Óbuda in the fifteenth century.[105] Another master, Bartholomeus Italicus from Zagreb was mentioned because he was robbed on his way home back from the market of Ptuj and asked for compensation.[106] A different case was registered in Bardejov, when the judge asked the town's council to approve Paulus Glaser's second marriage in 1576, because his first wife had left him for a soldier and taken all of his personal belongings.[107]

Written sources can also emphasize the type of products manufactured in the workshops. Glass workshops highlighting window glassmaking are most common. In the Pauline monastery of Budaszentlőrinc, frater Jacobus *fenestripar* made glass windows and also

[102] Csiffáry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 125–26; Csiffáry, *Magyarország üvegipara 1920-ig*, 61–62.

[103] Csiffáry, *Magyarország üvegipara 1920-ig*, 66; Jaroslaw Robert Vávra, *Das Glas und die Jahrtausende* (Prag: Artia, 1954), 172; H. Gyürky, *Üvegek a középkori Magyarországon*, 20.

[104] Csiffáry, *Magyarország üvegipara 1920-ig*, 74–75.

[105] Csiffáry, 68; H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215; H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 85.

[106] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215.

[107] Csiffáry, *Magyarország üvegipara 1920-ig*, 77; Kornél Divald, "Az üveg [The Glass]," in *Az iparművészet könyve*, ed. György Ráth, vol. 3 (Budapest: Athenaeum Irod. és Nyomdai Rt., 1912), 364.

taught the craft to the younger brothers.[108] The accounts from 1419 in Bardejov indicate the presence of two masters: Hannus and Kwmwl, who got paid for window glass making.[109] A surviving written source from the end of the fifteenth century describes the glazing of the church in the castle of Eger. The glass windows were made in a close by workshop in Bodony.[110] The account book of Estei Hippolit, the archbishop of Esztergom, shows that master John made and sold 5000 pieces of window glass ordered for a building in Esztergom in 1491. This is a particularly important case, because the workshop of master John can be identified with the glass production site excavated in Visegrád at the site on 5 Rév Street. Some aspects of this workshop will also be discussed in the part of this thesis dealing with the archaeological remains of glass production. Visegrád is a significant site in the history of Hungarian glassmaking as another workshop has also been excavated here.[111]

Unfortunately, in a few cases, one mention of a surname connected to glassmaking or a subtle reference to a workshop is not enough to verify the existence of production sites near to certain settlements. This was the case in Arpașu de Sus, where one mention from 1541 could not convince Magda Bunta and Imre Katona that a glass workshop had ever operated there.[112]

In conclusion, the written sources can provide detailed, supplementary information about the workshops and the craftsmen, but they cannot offer a clear picture about the structure of the glass workshop, or the manufacturing processes involved in glassmaking. However, they have proved to be useful in dating, because they give the exact year when the workshop was still in operation.

[108] Csiffáry, *Magyarország üvegipara 1920-ig*, 70; László Zolnay, *Az elátkozott Buda. Buda aranykora. [The cursed Buda. The Golden Ages of Buda]* (Budapest: Magvető Könyvkiadó, 1982), 400.

[109] Lajos Sághelyi, *A magyar üvegesipar története [The History of the Hungarian Glassmaking]* (Budapest: Üvegforrasztók, Üveg-, Porcellán- és Fayencefestők, M ozaikművesek és Tükörkészitők Ipartestülete, 1938), 73.

[110] László Zolnay, *Kincses Magyarország. Középkori művelődésünk történetéből [Treasures of Hungary. From the History of Our Medieval Culture]* (Budapest: Magvető Könyvkiadó, 1977), 269; Csiffáry, *Magyarország üvegipara 1920-ig*, 72.

[111] Mészáros, "15. századi üvegműhely Visegrádon," 686.

[112] Magda Bunta and Imre Katona, *Az erdélyi üvegművesség a századfordulóig [The glassworks in Transilvania until the turn of the century]* (Bukarest: Kriterion Könyvkiadó, 1983), 37.

Some information about glass workshops using non-destructive surveys as well as excavations

Artifacts, workshop waste, burned building materials with glass residue may indicate the location of a glass workshop. However, they can only provide limited information about the furnaces and the products manufactured there. These finds are typical found and located during non-destructive surveys and also archaeological excavations, where just a few pieces of glass slag or burnt bricks can often be found in secondary deposits.

Sometimes, the gathered information from a survey seems too vague to locate and describe a glass workshop. For example: in Csesznek a glass workshop was identified based on the presence of glass slag and a few bricks, found during a non-destructive survey in 1966.[113] It is possible that a workshop stood on the territory called Kőmosó close to the river, although this information is not sufficient to warrant further analysis. The situation is the same with the field survey carried out in Kerndorf. Pieces of glass slag, molten blue glass fragments and glass drops were found here.[114]

In 1969, close to Szatymaz-Jánosszállás, by the Katona bank, glass slag and pieces of molten glass fragments were found in the stratigraphic layers dated to the eleventh – twelfth century during a rescue excavation. On the basis of only these limited fragments, Gergely Csifféry suggested the an annealing furnace had stood here that could be heated up to 500-600°C.[115] This hypothesis seems unrealistic due to the fact that no other remains were found during the excavation which could be connected to glassmaking such as in situ furnace remains, fire resistant clay pots or bricks. The existence of a standalone annealing furnace is not likely, because the craftsmen needed to ensure by the placement of the furnaces close to each other that the freshly finished products could be moved from the glass furnace to the annealing kiln

[113] Csifféry, *Magyarország üvegipara 1920-ig*, 78.
[114] Csifféry, 79.
[115] Csifféry, 61.

as fast as possible, otherwise they would easily break. Only a melting furnace used for beadmaking could function alone and on a higher temperature than 600°C.[116]

During another excavation, the remains of glassmaking was unearthed in Esztergom-Szentkirály, between the Danube and the creek draining the water from Bottyán Lake. Glass slags and beads were found in the layers dated to the twelfth - thirteenth century. Gergely Csifféry also suggests that a glass workshop operated here, , an Árpád Period smithy was uncovered by János Gömöri in Esztergom - Kovácsi.[117] Nevertheless, the presence of a nearby smithy and fragments of glass slag recovered here do not seem to offer enough evidence that an entire glass workshop operated in Szentkirály. But it is also possible that the workshop could have specialized in glass bead production as in Szatymaz-Jánosszállás because glass bead making only required a small, simple clay kiln or even an open hearth. The bottom of such hearths was lined with stones and coated in clay. The important issue was whether the small kiln could produce and endure temperatures higher than 600 - 900°C. If such a bead making workshop stood here it would have required only colored glass rods and a few iron tools to operate the workshop. [118]

The same could be said about the artefacts found closeto the Northern Gate of the Buda Palace. Based on the few pieces of glass slag and fragments of crucibles, László Zolnay and Jolán Balogh assumed the existence of a fourteenth – fifteenth century glass workshop located somewhere in the vicinity of the site.[119] Other small finds have been brought to light in

[116] István Fórizs, "Üvegkészítés Magyarországon a kezdetektől a XVIII. századig [Glassmaking in Hungary from the beginning to the eighteenth century]," *Bányászat. A Miskolci Egyetem Közleménye* 74 (2008): 119–20.

[117] Csifféry, *Magyarország üvegipara 1920-ig*, 61; János Gömöri, *Az avar kori és Árpád-kori vaskohászat régészeti emlékei Pannoniában. Magyarország iparrégészeti lelőhelykatasztere I. Vasművesség. [The Archaeometallurgical Sites in Pannonia from the Avar and Early Árpád Period. Register of the Industrial Archaeological Sites in Hungary I. Ironworking]* (Sopron, 2000), 92–93.

[118] In 2015, in Ribe a successful archaeological experiment was carried out to understand more about the process of glass bead making. Marta Krzyżanowska and Mateusz Frankiewicz, "An Archaeological Experiment with Early Medieval Glass Bead Production in an Open Hearth – Results," *Slavia Antiqua*, no. LVI (2015): 109–27.

[119] Zolnay, *Az elátkozott Buda*, 423; Jolán Balogh, *Mátyás király és a művészet [King Matthias and the Art]* (Budapest: Magvető Kiadó, 1985), 110.

various different excavations around the Palace, including a fragment of a blowpipe, which was found without context.[120] However, it is also probable that the finds lie in secondary deposits close to the remains of an as yet unknown workshop.[121] A small crucible with parison still in it, was found in the palace courtyard close to the chapel.[122] Several glass workshops must have operated in medieval Buda which still remain undiscovered; but I am more in agreement with Katalin H. Gyürky who thinks that these finds on their own that these finds are not enough to precisely locate any of the glass workshops that probably stood close to the Norther Gate or in the Palace itself.[123]

In 2012, the badly damaged remains of a glass workshop were found during archaeological observation work and excavation in Budapest, at 54 Váci Street. Judit Zádor identified the melting furnace a three-story glass furnace but did not provide further detailed information about their structure (Figure 17). A large pit with burned clay and stones near to the furnaces were unearthed. According to her, these could be the remains of an annealing furnace (Figures 18-19). Based on the relative dating of the ceramics from the workshop, it operated in the thirteenth century.[124] However the report fails to convincingly demonstrate the existence of this workshop due to the lack of further evidence.

In 1984, Péter Gróf and Dániel Gróh excavated a fourteenth-fifteenth century glass workshop in the medieval workshop district of Visegrád, east of the Apátkúti creek, close to the Danube. Here, they found a pit system with burned remains surrounded by four postholes with charred wood residues (Figures 20-21). In the middle, there was a burned, oval stone surface. The finds found near to it comprised fragments of frits, glass drops, glass slag and

[120] Balogh, *Mátyás király és a művészet [King Matthias and the Art]*, 110.
[121] Interpretation suggested by József Laszlovszky.
[122] Imre Holl, "A budai várpalota egy középkori rétegsorának elemzése [The Analysis of a Medieval Layer from the Castle of Buda]," *Archaeológiai Értesítő* 114–115 (1988 1987): 188.
[123] H. Gyürky, *Üvegek a középkori Magyarországon*, 21.
[124] Judit Zádor, "Üveggyártó műhely és lakóépület részlete a középkori Pest területén. [A glass production workshop and a detail of a dwelling in the territory of medieval Pest]," *Aquincumi füzetek* 19 (2013): 108–9.

burned bricks. These imply the presence of a glass workshop, although the furnaces and the workshop cannot be reconstructed due to the poor conditions of preservation at the site. Northeast of the excavated stone surface, there was a deep pit containing fragments of crucibles, one with a special rectangular shape. Finished products also came to light there. A chemical analysis showed that the fragment of a prunted beaker found there was made from the same materials as the beakers found during excavations at the Royal Palace. For this reason, Edit Mester suggested that that the workshop that stood at 34 Fő Street must have produced glass products for the royal family.[125]

In 1973, Emese Lovász excavated the Pauline monastery in Diósgyőr – Majláth.[126] A few pieces of glass slag and frits were found during the excavation. Gergely Csifféry, thus, hypothesized that a fourteenth-fifteenth century glass workshop operated in the monastery.[127] Again it is possible for a Pauline monastery to have had a glass workshop, and produce glass for themselves, but glass slag and molten glass fragments also can appear in the destruction layers of buildings. However, in cases like this, it is also possible that the glass fragments are connected to one of the building periods of the monastery. To produce specially stained glass for the windows, temporary glass workshops may have been established on or near to the site. Such was the case of the Abbeys of Glastonbury and Barking in the tenth century. Evidence suggests that sometimes these temporary workshops were not established and run by the monks themselves but run by glaziers. An example of this is found in the Parisian tax book showing that the glassmaking masters located their workshops near to churches.[128]

[125] Edit Mester, *Középkori üvegek [Medieval glasses]*, Visegrád régészeti monográfiái 2 (Visegrád: Visegrádi Mátyás Király Múzeum, 1997), 7.

[126] Emese Lovász, "A diósgyőri pálos kolostor 1973. évi feltárása [The Excavation of the Pauline Monastery at Diósgyőr in 1973]," *A miskolci Herman Ottó Múzeum Közleményei* 19 (1981): 76.

[127] Csifféry, *Magyarország üvegipara 1920-ig*, 73–74.

[128] Madeline H. Caviness, *Stained Glass Windows* (Turnhout - Belgium: Brepols, 1996), 49; Meredith Parsons Lillich, "Gothic Glaziers: Monks, Jews, Taxpayers, Bretons, Women," *Journal of Glass Studies* 27 (1985): 72–92.

Conclusion

The aim of this chapter was to analyze the available information about the glass workshops that appearing in one form or another in written sources such as litigation records, letters, and reports. It is no surprise that Useful names, places and dates are mentioned in these sources; however, they do not describe the workshop or the kilns.

The other main goal of this chapter was to identify and analyze the archaeological finds that mark the presence of a glassmaking site. Through them I examined the reports of non-destructive archaeological surveys and excavations where only limited glassmaking evidence was found. In some cases, such as Csesznek, Budapest-Váci Road or Diósgyőr-Majláth the finds do not in themselves prove the workshop had stood there, although its existence is possible. In other cases, there is no doubt that a glass workshop had indeed been present, although the phenomena detected are not sufficient to identify the production technology. In the cases of Szatymaz-Jánosszállás and Esztergom-Szentkirály, it is probable that instead of the production of glass vessels, the finds that came to light reflect use of a simpler technology that could have been used to make glass beads.

Chapter 3 - Excavated glass workshops

Introduction

The following chapter moves on to describe and analyze the glass workshops in greater detail by reviewing the excavated sites. Unfortunately, these sites are not numerous. All four known sites were established in different environments, had different owners and serviced varying markets. On the other hand, this diversity permits us to understand more of the variable manufacturing processes and the way the workshops adapted to their local environment and potentials.

Pásztó

The earliest excavated glass workshop from Hungary is located at the monastery of Pásztó. In the beginning of the twelfth century, Benedictine monks lived there, and according to Ilona Valter, they had abandoned the monastery before the end of the century.[129] In 1190, Béla III established a Cistercian monastery on the same spot and the monks came here from their monastery at the Pilis. Until 1265, the ruler was the patron of the monastery when Stephen the younger king gave the patronage to master István Rátót, the queen's equerry. The Pásztói and Tari families (from the kindred of Rátót) owned the settlement until 1526. After the battle of Mohács in 1526, the monks fled from Pásztó. Some of them ended up in Heiligenkreuz.[130]

[129] Ilona Valter, "Adatok a pásztói monostor gazdasági életéhez [Details of the economic life of the monastery of Pásztó]," in *Historia est... Írások Kovács Béla köszöntésére*, ed. Gergely Csiffáry (Eger: Regiocon Kft, 2002), 425; Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban [An Arpadian period (eleven - thirteen century) glass workshop and smithy in the monastery of Pásztó]," *Archaeologiai Értesítő* 140 (2015): 215.

[130] Valter, "Adatok a pásztói monostor gazdasági életéhez [Details of the economic life of the monastery of Pásztó]," 425.

The monastery stood on a small hill, it was encircled by the Malom (Mill) creek, which supplied water to the watermill at the bottom of the hill and fed the fishponds. On top of the hill the buildings of the monastery connected from the south side to the three-nave church in a U shape (Figure 22-24). Near to it there were a glass workshop and a smithy. According to Ilona Valter in 1230 conflagration destroyed the buildings, and afther that the workshops were not rebuilt.[131]

The building of the glass workshop was oriented east-west and comprised a two-roomed (20 x 7 m) building (Figure 25). It had two entrances, one on the eastern side, which led to the bigger room. The other door was on the south side, leading to a smaller room. In Ilona Valter's opinion, the walls could not have been higher than 1.5 m and, based on the line of postholes running through the middle of the building, the structure must have had a timbered pitched roof. In the bigger room stood two furnaces and one hearth. In the northern corner stood a rudimentary, ovoid furnace (Figure 25). The kiln's layout suggests that its opening faced to the east. According to Ilona Valter, this furnace could be heated up to 800°C and worked as a "pre-heating" kiln. The furnace could only heat up one 10-15 l crucible at a time.[132] In the south-west corner of the bigger room stood a circular hearth, which could be used for burning beech wood, claims Ilona Valter. Ash and some charcoal could be observed on its heating surface. The rectangular melting furnace stood almost in the middle of the eastern side of the building, close to the hearth. A fifteenth century waste pit and the eighteenth-century school buildings destroyed most of the eastern part of the building and the upper parts of the annealing furnace. Only the foundation row survived, comprised of rhyolite and clay plastering. The opening for heating up the melting furnace was on the eastern side. Ilona Valter notes that there was no trace of glass in the immediate vicinity of the furnace. In the southeast corner of the

[131] Valter, 426.
[132] Valter, *Pásztó a középkorban [Pásztó in the Middle Ages]*, 76-77.

smaller room stood the annealing furnace. It had a grate with holes above the firebox and was made from clay.[133] Only a few molten glass fragments and glass slag were unearthed besides the in situ remains. Ilona Valter reconstructed the furnaces (Figure 27) and the workshop based on Theophilus Presbyter's description from the *On Diverse Arts* [134] Essays and papers have not yet been published about it, but her interpretation has been argued orally. The hypothesis overlooks the impractical placement of the furnaces. For example, the melting furnace and the hearth are located too close to each other so that they probably they could not have been used at the same time. The hypothetical structure of the kilns has also been disputed the *in situ* remains are scarce and there is little remaining building material to convincingly reconstruct the kilns. Moreover, the chemical analysis of the small number of glass fragments, only four samples, show indications of a unique glassmaking technology. Some of the samples were poor quality, contaminated, greenish glass fragments. They turned out to be from so-called short glasses, which had to be heated nearly to 1300°C and could be worked only over a limited amount of time. The analysis suggests that this type of glass was mostly useable for pressing into molds. The other two samples were cleaner and more translucent. They were categorized as being from long glasses, which means that the melting point of this glass must have been around 1100°C, and the glassblowers had more time to shape this glassware compared to the short glasses. These samples were more suitable for blowing glass vessels or windowpanes.[135] The two type of glasses are technically so different, that it is hard to imagine that they were made in the same glassworks.

[133] Valter, 78–79; Valter, "Glass workshop and smithy in Pásztó," 203–4.
[134] Valter, *Pásztó a középkorban [Pásztó in the Middle Ages]*, 80; Valter, "Glass workshop and smithy in Pásztó," 213–16.
[135] Valter, "Glass workshop and smithy in Pásztó," 222–24.

Diósjenő

A special glass workshop site was found in a forest area close to Diósjenő, on the banks of the Kemence Brook, bordering Nagy Gál meadow (Figure 29). The first workshop area that was discovered was in a corner plot surrounded by a two-way branching dirt road (Figure 30). The second one lay only 40 meters away to the southwest, while a third workshop was found 285 meters away to the east (Figures 30-31).[136]

Glass workshop I was excavated by Katalin H. Gyürky and Zsuzsa Miklós in 1987. They found large amounts of broken and molten glass, workshop waste, crucible fragments and even a few tools. Only the lowermost rows of stones and the heating duct survived from the storage building and the three unearthed kilns, not enough information for an accurate reconstruction. The longitudinal axis of the first kiln (Figure 32) is oriented northwest to southeast. It was constructed from undressed stones and the clay plastering was still visible on the north and the west sides. The interior was renewed once because there was two layers of clay plastering. The renewal took place in the fourteenth century, based on the dating of ceramics found in the second, renewed layer. The second furnace (Figure 32) was 26% larger than the first and had an opposite orientation (northwest to southeast). Unfortunately, only a few stones remained from the kiln. The third furnace (Figure 33) was the largest, and its longitudinal axis was oriented north to south. The heating duct was in the middle, a carved stone indicated the place of the heating opening at the southern end. At the opposite northern side, the lower part of a carved-stone ventilation opening was found. The kiln was built from undressed andesite stones and covered with clay plastering. The stones were burned and some of the stones on the eastern side of the heating duct, close to the supposed ventilation opening, were covered with greenish glass residue. Near to the furnace were found several curved bricks.

[136] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 69.

Katalin H. Gyürky postulates that the bricks were mostly used to purl the openings and the bottom of the furnace.[137] The layout of the workshop shows similarities to the thirteenth century glass workshop in Steimcke. That workshop had a large, round furnace with two close by smaller, ovoid furnaces. Like the workshop in Diósjenő, it mostly produced window glass.[138]

Glass workshop II was located on the banks of Kemence Brook although it also had access to another water source, which still retains the memory of the former workshop in its name: "Üveghuta kútja" (Glass house well).[139] The workshop was excavated by Edit Mester and Zsuzsa Miklós. The layout of the workshop was mostly parallel to the first one: although it was also equipped with two furnaces and a storage building (Figure 33). The longitudinal axis of the first furnace is oriented northeast to southwest. The rectangular kiln had a long heating duct made of flat stones embedded in clay. The inner side of the vault was plastered with clay and a few fragments of burned clay were found in the firebox with the imprint of wattle. At the mouth of the furnace, the stones were covered with white and green glass, and several crucibles and glass slag fragments were unearthed from this area. The stones of the firebox were heavily fragmented and burned red, which indicates 1000-1400°C high temperatures. Based on this evidence, Edit Mester suggests that this could have been the melting furnace. The secondly feature recovered was the storage building for the finished products. The walls and the floor were made from flat stones placed in clay, almost like the lower part of the furnaces. Edit Mester suggests that the upper part was constructed of wood. The door of the building was on its northeastern side (Figures 33-34). The second furnace had the same orientation as the first one. This square kiln could have functioned as a pre-heating or

[137] H. Gyürky, 69–71.

[138] Besides glass windowpanes, the Steimcke workshop also produced small animal figures like dogs, horses and small mythological statues like centaurs. Kurzmann, *Mittelalterliche Glastechnologie*, 86.

[139] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 69. The Üveghuta kútja means the well of the glass workshop.

annealing furnace. Edit Mester proposed that the workshop also possessed a third kiln, similar to that found in the first glass workshop, however the modern road has destroyed it.[140]

Lastly, G*lass workshop III* operated four furnaces (Figure 35). The longitudinal axis of the first furnace is oriented northeast to southwest. This was the largest furnace, and it was constructed from large, undressed stones. The stones near to the firebox were fragmented and burned red. Many of the stones and bricks that came to light were covered with white and green glass. Among these stones and bricks were found many pieces of glass slag as well as finished products, crucibles and a few iron tools. Based on these finds, Edit Mester described the first kiln as a melting furnace. The second furnace was oriented northeast to southwest. It was made using the same technology as the first, but the stones were not burned. During the excavation, many beech nuts were found in the burned clay of walls of the furnace. These nuts were harvested in June-July and, according to Edit Mester, fell on the wet clay during the building of the furnace. The third furnace faced in the same direction as the others. The quality of the walling and the fact that fragments of the crucibles were used for secondary purposes as building material suggests that this furnace was built in a hurry. It is also possible that it was built later because it used waste from former workshop activity as part of the construction material. Pieces of several glass slag, molten glass fragments, stones covered with green glass and a few tools were found close to this furnace. The fourth furnace was oriented in the same direction as the others and built in the same way as the first and second furnaces. The stones were less burnt, suggesting that this could have been the annealing furnace, operating at lower temperatures.[141] In terms of dating, Katalin H. Gyürky notes that glass workshop I operated from the second half of the thirteenth century until the second half of the fifteenth century.

[140] Mester, *Középkori üvegek [Medieval glasses]*, 8–9; Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 659.

[141] Mester, *Középkori üvegek [Medieval glasses]*, 9–10; Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 659; Edit Mester, "Research of Medieval Glass Vessels and Glasshouses in Hungary," *Beiträge Zur Mittelalterarchäologie in Österreich* 19 (2003): 61.

After the first workshop was abandoned, workshops II and III were established in the second half of the fifteenth century. H. Gyürky suggests that the expanding market justified the establishment of the two bigger workshops. They had to move the workshops due to their growing need for beech and other types of wood ash. The analysis of the glass fragments from the workshops shows the same chemical composition, supporting the idea of continuity between the workshops. In workshops II and III, only glass window fragments were found among the finished products. This suggests that the glass workshop was specialized making only window glass in large quantities for the nearby settlements and castles.[142]

Pomáz-Nagykovácsi

The Pomáz-Nagykovácsi site is located relatively close to Budapest, in the valley of Dera Stream, in the Pilis mountains (Figure 36). The site consists of two sections: the first is Kovácsi village, which lies in the valley close to the Dera Stream and the modern road to Pilisszentkereszt.[143] The name Kovácsi suggests the presence of smithing or blacksmiths because *kovács* means blacksmith in Hungarian. This seems to be attested by the fact that iron slag and other traces of iron processing was found on the site on the western side of the road during the excavations led by Tamás Repiszky.[144] The village was part of the royal estate, the

[142] Mester, *Középkori üvegek [Medieval glasses]*, 10.

[143] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi: The Finds and Heritage Interpretation of an Archeological Site," 240; Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom Pomáz-Nagykovácsi pusztán [Glassmaking in the Pilis and a medieval church in Pomáz-Nagykovácsi]," 80; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 16.

[144] Tamás Repiszky, "218. Pomáz, Kovácsi," *Régészeti Kutatások Magyarországon*, 2001, 205.

royal forest of Pilis and it was populated in the Árpádian Period.[145] There were no signs, however, of late medieval habitation.[146]

The other part of the site is situated east of the modern road on a 20m high hill. Here are located the ruins of a small, single-nave church surrounded by other buildings. This part of the site is in the focus of this chapter, because fragments of kilns and traces of glassmaking were found in the buildings and even in the church itself.[147]

The existence of the site was noted in the eighteenth century when the landowning Wattay family used medieval charters to prove their rightful ownership of the territory and the former Kovácsi village following the Ottoman occupation.[148] The ruins were still visible and even indicated on nineteenth century cadastral maps, labelled "Pusztatemplom" (Figure 37). However, actual research on the site was only started in 1927 by a non-professional archeologist, László Krompecher, who was a professor of architecture at the technical university in Budapest. Based on the visible remains, he theorized it was the Cistercian Abbey of Pilis. His later excavations revealed a single-nave church with a semicircular apse, oriented towards the east-northeast and a rectangular building standing northeast from the church.[149] On his ground plan, he interestingly showed the building as not being in line with the church

[145] József Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains. The Long and Complex History of an Árpád Period Village Church," *Hungarian Archeology* Winter (2014): 3; József Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]," in *A ciszterci rend Magyarországon és Közép-Európában [The Cistercian Order in Hungary and Central Europe]*, ed. Barnabás Guitman and Sándor Őze, Művelődéstörténeti Műhely-Rendtörténeti konferenciák 5 (Piliscsaba: Pázmány Péter Katolikus Egyetem Bölcsészettudományi Kar, 2009), 194.

[146] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 9.

[147] Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]," 204; Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 8–9; Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 240.

[148] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 3.

[149] Krompecher László, "A pilisi ciszterci apátság és a pilisszentkeresztnek szentelt pilisi pálos kolostor építészeti maradványai [Architectural Remains of the Cistercian Abbey of Pilis and the Pauline Monastery of Pillis Dedicated to the Holy Cross of the Pilis]," *A Magyar Mérnök- és Építész-Egylet Közlönye 62. évfolyam*, no. 49–50 (1928): 329–33; László Krompecher, "A Pilisi Apátság Romjainak Fellelése [Finding the Ruins of the Abbey at Pilis]," *Technika. A Magyar Mérnökök Lapja* 1–10, no. 15 (1935 1934): 36–37; Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 2; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 16.

(Figure 38). A local amateur archaeologist, Sándor Sashegyi, was next to continue Krompecher's work and criticize it. He also created a ground plan based on the visible remains and his excavations. He depicted three buildings, in line with the church, and surrounding it on three sides in the shape of the letter U (Figure 39). He also incorrectly identified the site as the Holy Cross Monastery of the Pauline Order.[150] In 1996, a survey and reconstruction drawing showed that Krompecher's ground plan was the more accurate of the two, depicting the wings as being mismatched to the church (Figure 40).[151] Meanwhile, Tamás Guzsik tried to identify the site with the Pauline Monastery of Insula Pilup, but later this theory was also disproved.[152] The debates came to an end in 2009 József Laszlovszky after presented a new interpretation based on a charter from 1254, which described Kovácsi village as a property owned by the Cistercian Monastery of Pilis. He proposed that the church first belonged to Kovácsi village but later it became the chapel of a manorial complex (grange) of the Cistercians.[153] In 2011, research on the site continued in the form of geophysical surveys, complementing the excavation of the church and the western wing (Figures 42-43).[154]

[150] Belitzky János and Sashegyi Sándor, *Pomáz*, A magyar föld és emlékei (Budapest: Nyomdavállalat, 1939), 20–22; Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 2; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 16.

[151] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 3–4; Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]," 207–8.

[152] The Insula Pilup monastery was mentioned in a contemporary list, which placed it in another location. Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 2–3; Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]"; Beatrix Romhányi, "'Páloskolostorok a Pilisben' [Pauline Monasteries in the Pilis]," in *LaudatorTemporis Acti – Tanulmányok Horváth István 70 Éves Születésnapjára*, ed. Edit Tari (Esztergom: Balassi Bálint Múzeum, 2012), 223–27; László Solymosi, "Pilissziget vagy Fülöpsziget? A pálos remeteélet 13. századi kezdeteihez [Pilis Island or Fülöp Island? On the Beginnings of the Pauline Hermits' Life in the thirteenth century]," in *Emlékkönyv Orosz István 70. születésnapjára (Festschrift for the 70th Birthday of István Orosz)*, ed. János Angi and János Jr. Barta (Debrecen: Multiplex Media, 2005), 11–23.

[153] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 3–4; Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]," 203–4; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 16.

[154] József Laszlovszky, "Középkori templom és üveggyártó műhely feltárása - rövid jelentés. [The excavation of a medieval church and glassmaking workshop - short report]," *Altum Castrum*, 2012, 2–4; Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 4–5; Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom," 81–82.

The small excavated (7m x14m), single nave church with a slightly less wide semicircular apse was oriented towards the east-northeast. Its entrance was on its southern side. The pillars found in the western part of the church suggest existence of a former western gallery.[155] The estimated foundation of the parish church may have been in the second half of the twelfth century, when it belonged to Kovácsi village. This was confirmed by a number of graves from the Árpádian Period, unearthed along the northern and southern sides of the church.[156] However, the royal servant's village was abandoned during the Mongol Invasion (1242) and with it the parish church and the churchyard. In the second half of the thirteenth century, the territory was owned by the Cistercian order. The former parish church became the chapel of a monastic grange. Three surrounding workshop buildings were established here during the fourteenth century. The lay brothers working here, formed terraces for agricultural cultivation and established a water management system by creating channels, dams and fishponds.[157] The second and greater change to the church and its surrounding buildings came when the grange began a new industrial activity. Traces of glass production were found in the western wing and even in the church. During the excavations, remains of the furnaces, 15 kg of glass shards, fragments of melting pots, bricks and unfinished glass product were found. This glassmaking period lasted until the Ottoman occupation in the mid-sixteenth century, when the Cistercians abandoned their grange.[158] The remains of the buildings slowly started to crumble. In the sixteenth to seventeenth centuries, lead bullets were manufactured inside the remains of the buildings. Later, the church only appears on maps as a ruin. [159]

[155] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 7–8; Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom," 82–83.

[156] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 8; Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom," 81.

[157] Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 9.

[158] Laszlovszky et al., 10; Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 240.

[159] Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom," 82.

So far, this section focused on the surroundings, research, and historic periods of Nagykovácsi. But to better understand the procedure of glassmaking and how the glass workshops operated at this site, it is necessary to make a more detailed description and analysis of the workshop buildings and the glass kilns. The building wing surrounding the church from west, east and north were built when the Cistercians owned the territory. Each workshop building was about 28-30 m long and 8-10 m wide. These buildings were divided into smaller and larger rooms by inner walls that changed position depending on the period. So far, traces of glass production have been found only the eastern and western wing. Whether the north wing could have been the storage building for the finished products or the living quarters of the lay brothers, requires further archaeological surveys and research. However, in the western part of the eastern wing, László Krompecher found the remains of a glass kiln. Due to the narrowness of the opened trench, the structure and the layout of the furnace remains unclear.[160] During later surveys and excavations in this part, however, burnt, distorted bricks were found, which most likely belonged to a glass kiln. The western building displaysa clearer picture with its excavated annealing furnace and the burnt layers around it, flooded with refractory melting pot fragments, bricks, frits and glass residue. The *in situ* remains of the annealing furnace on the eastern side of the building has a rectangular form. Its foundation was made of stones, many of them burnt. On top of the foundation, on the southern end, two parallel rows of bricks were revealed. These may have functioned as the fire funnel of the annealing furnace. Four postholes were also found on the eastern side of the kiln. Two of them suggested later rebuilding of the same structure. The posts possibly supported a roof to shelter the kiln from the elements.[161] Based on the west workshop building's size, layout and findings, Karen Stark and József Laszlovszky argue that it might have been similar to the fifteenth century glass workshop found

[160] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 241.

[161] Laszlovszky and Stark, 242–44; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 17.

at Visegrád, 5 Rév Street.[162] That workshop operated in a stone building, divided into two workshops, and four rooms. In every room stood an ovoid or rectangular kiln.[163] Another workshop that resembled this one may have operated in Germagnana, near Gambassi in the thirteenth to fourteenth century. That glass workshop had five furnaces, and three of them operating in building that was smaller (16 m x 9 m) than the western wing on the Pomáz site. Inside stood an ovoid main melting kiln and two rectangular, auxiliary working furnaces.[164]

Surprisingly, evidence for glassmaking was also unearthed inside the chapel. Its former flooring comprised of square bricks was removed. Afterwards - presumably the lay Cistercian brothers - brought in yellow clay and levelled it in some parts, to make a foundation for the glass furnace or furnaces. A heavily burnt clay surface was found under the few centimeters thick layer of glass shards and fragments of half-finished products in the middle of the nave (Figure 44). In the debris were found refractory crucibles, melted glass and curved bricks. Unfortunately, there are not enough *in situ* remains from the upper structure of the furnace to reveal the original shape and size of it.[165] At the same time, other find such as the curved, refractory bricks distributed between the transformed chapel and the western workshop suggest that they belonged to a glass melting furnace, possibly destroyed during overheating. These bricks indicated that a ribbed round or ovoid furnace operated somewhere in the site.[166] However, there are less *in situ* remains of the furnaces or else the main furnace has not yet been

[162] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 244–46.

[163] Mészáros, "15. századi üvegműhely Visegrádon"; Orsolya Mészáros and Mátyás Szőke, "A visegrádi 15. századi városi üvegműhely [The fifteenth century glass workshop in Visegrád]," in *Hunyadi Mátyás, a király. Hagyomány és megújulás a királyi udvarban 1458-1490 - Kiállítási katalógus*, ed. Enikő Spekner et al. (Budapest: Budapesti Történeti Múzeum, 2008), 345–47.

[164] Kurzmann, *Mittelalterliche Glastechnologie*, 89–90.

[165] Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom," 83; Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 243; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 17; Edit Megyeri, "Üvegek a Visegrád Rév utca 5. szám alatt feltárt üvegműhelyből és Pomáz–Nagykovácsi lelőhelyről [Glass Finds from the Glass Workshop at 5 Rév Street Visegrád and at the Excavation Site of Pomáz–Nagykovácsi]," in *A múltnak kútja. Fiatal középkoros régészek V. konferenciájának tanulmánykötete [The Fountain of the Past. Study Volume of the Fifth Annual Conference of Young Medieval Archaeologists]*, ed. Tibor Ákos Rácz (Szentendre: Ferenczy Múzeum, 2014), 76–77.

[166] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 243.

found. Karen Stark and József Laszlovszky proposed that the kilns here had parallels with the "northern furnace type".[167] This type of furnace structure could have various shapes like rectangular, ovoid or even U- or horseshoe-shaped. The workshops usually consisted of a main melting or working furnace, surrounded by or in close proximity to the auxiliary furnaces. This type of workshop layout is more common in Northern and Central Europe.[168]

Considering that the Nagykovácsi glass workshop was established and owned by the Cistercians, the workshop in Schönbuch forest can be mentioned as a parallel. It was owned by the Cistercian monastery of Bebenhausen, although it continued in use later, until around the end of the fifteenth century. Both Nagykovácsi and Schönbuch seemed to have manufactured a whole range of glass products from window glass to various vessels. But Schönbuch's main product were the large amounts of window glass for the building projects carried out by the monastery and the Dukes of Württemberg. The similarities seem to stop here, because the structure of the site differs from the workshop from Nagykovácsi. The workshop in Schönbuch was not located inside a building or buildings and it consisted of three furnaces: one melting and two auxiliary kilns surrounded by drainage. One of the subsidiary furnaces was long enough to work as a tunnel lear where the smoothed window glass could gradually cool down the.[169]

[167] Laszlovszky and Stark, 243.

[168] Charleston, "Glass Furnaces through the Ages," 22–23; Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 243; For more about the different type of furnaces, see: Kurzmann, *Mittelalterliche Glastechnologie*; Charleston, "Vessel Glass"; Charleston, "Glass Furnaces through the Ages."

[169] Kottmann, "Reconstructing Processes and Facilities of Production: A Late Medieval Glasshouse in the Schönbuch Forest," 35–36; Kottmann, "Die Glashütte Glaswasen Mittelalterliche Glastechnologie im Schönbuch," 38–39; Further reading about Schönbuch: Frommer and Kottmann, *Die Glashütte Glaswasen im Schönbuch. Produktionsprozesse, Infrastruktur und Arbeitsalltag eines spätmittelalterlichen Betriebs*.

Visegrád

Another glass workshop was unearthed in Visegrád, near to the Danube at 5 Rév (Ferry) Street (Figures 45-46). The 1700 m2 site is on private property. A rescue excavation took place here in 1950. During the dig, Miklós Héjj found traces of the thirteenth-fourteenth century settlement and argued that the walls of the crumbling building were medieval in origin. The next chance to research the buildings came in 2004-2005. Orsolya Mészáros and Mátyás Szőke excavated about two thirds of the property (Figure 47).[170] A burnt wooden structure and a clay flooring was found in the northern part of the property. The building dated back to the fourteenth century. The remains of the medieval road were unearthed, running in front of the wooden building, on its northern side. South from the wooden building, the foundations of a north-south oriented stone building was revealed during the excavations. A 12 m x 8 m cellar was found under the building. A window opening was found its southern side and on its east side an entrance was unearthed. Based on the finds from this building, it could be dated to the fourteenth to fifteenth century. South of this stone building stood another rectangular, north-south oriented medieval building, which was used as the building of the glass workshop. The area between these buildings and the nearby well have not yet been excavated. However, a well and another building is visible near the workshop building. [171] Further archaeological surveys or excavations are required to identify which building might have been the storage room for the finished products and to locate where the living quarters of the glassblowing masters and workers are.

[170] Orsolya Mészáros, "Glass Art in the Middle Ages in Hungary," in *Glasarchäologie in Europa. Regionen - Produkte - Analysen. Beiträge Zum 5. Internationalen Symposium Zur Archäologischen Erforschung Mittelalterlicher Und Frühneuzeitlicher Glashütten Europas*, ed. Eva Černá and Peter Steppuhn (Most: Ústav archeologické památkové péče severozápadních Čech, 2014), 168–69, https://core.ac.uk/download/pdf/95356055.pdf; Mészáros, "15. századi üvegműhely Visegrádon," 675; Mészáros and Szőke, "A visegrádi 15. századi városi üvegműhely [The fifteenth century glass workshop in Visegrád]," 345.

[171] Mészáros, "15. századi üvegműhely Visegrádon," 675–78.

The second stone building, which later became a workshop was originally constructed as a dwelling house in the early fourteenth century. In the first period, it only had three rooms, all of them with brick flooring. The fireplace in the first room (from the south) was also built and used at this time. A glass workshop was founded inside the building in the second half of the fifteenth century. A dividing wall was put up to create the fourth room (from south) at this time. Therefore, the workshop building must have had rooms of a similar size. It is possible that the attached room was built in this period. In its heyday, the workshop must have supplied the royal building projects in Visegrád and Esztergom. The account-book of Hippolit d'Este, the archbishop of Esztergom, has a record concerning Johannes glassmaking master delivering 5000 windowpanes from Visegrád in 1491.[172] The workshop was abandoned peacefully in the early sixteenth century, before the Ottoman occupation. During the sixteenth to seventeenth centuries, the building was partially destroyed. However, in the seventeenth to eighteenth centuries, two, connected baroque buildings were erected here. After renovation in the nineteenth century, the building stood in this form until a conflagration in the 1970s.[173]

The workshop building (29 m x 10 m) was established in the fourteenth century and was divided into two workshops. There was no doorway between these separated workshops, but both were divided into two rooms (Figure 48). All four rooms possessed an ovoid or rectangular kiln. The northernmost room had a hard-packed mud floor, which was lower than the brick flooring in the other rooms. There was also a smaller room attached to the northwest corner of the workshop building. This attachment was 3 m x 3.4 m in size and 4.5 m deep. Its walls were thinner than the workshop's outer walls. It was possibly used as a trash pit, because curved bricks, debris, half-finished glass products, melted glass, glass residue and, refractory crucibles were found here. All the buildings entrances faced to the east and all the rooms could

[172] Mészáros, 686.
[173] Mészáros, 679.

be approached from outside. The only doorway on the western side lead to the small, attached room, although later this door was walled-in.[174]

The southern workshop consisted of two rooms. The first room (6.3 m x 7.5 m x 6.7) had a brick floor, missing in some parts or purposedly cut out to dig post-holes (Figure 49). On the western side, the flooring sunk, and in the fifteenth century the glassworkers had to level it with clay. In the middle of the room stood an ovoid glass furnace (3m). It was oriented northwest-southeast with its opening facing southeast. Unfortunately, the opening for the firebox did not survived, because the northeast part of the furnace was destroyed. But the combustion tube was surrounded on both sides with curved bricks. The eastern side of the kiln was bordered by post holes. On the western side, a few stone slabs were integrated into the floor and larger stones connected to the side of the furnace in the shape of the letter "U". Orsolya Mészáros has entertained the possibility that this could have been a small wall where firewood could be kept.[175] However, there is another possible explanation: on the Taunus ridge, Peter Steppuhn excavated and analyzed a glass workshop (fourteenth to seventeenth centuries) and found a similar U shape attachment to the main furnace. He suggests that it could mark another opening to the combustion chamber to create more draught, while firing up the kiln.[176]

The second room from the south connected to this workshop was smaller (4.5 m x 6.8 m). It had also brick flooring, sunken on the northeastern side. The rectangular kiln (2.8 x 3m) stood in its northwest corner (Figure 50). It was made out of large bricks with a small combustion tube. In front of the firebox opening, on the eastern side, there was an ash pit. The space featured a large working area on the southern side. The working surface was higher than the firebox and in front of it a higher brick floor had been constructed.[177]

[174] Mészáros and Szőke, "A visegrádi 15. századi városi üvegműhely [The fifteenth century glass workshop in Visegrád]," 345–47; Mészáros, "15. századi üvegműhely Visegrádon," 678; Mészáros, "Glass Art in the Middle Ages in Hungary," 84.

[175] Mészáros, "15. századi üvegműhely Visegrádon," 685.

[176] Steppuhn, "Archäologie einer Glashüttenlandschaft – Der Hochtaunus," 47.

[177] Mészáros, "15. századi üvegműhely Visegrádon," 681.

The third room (5.5 m x 6.8 m) belonged to the second workshop with a layout that was was almost identical to that of the second room (Figure 51). The room had also had brick flooring, missing on the northeastern side. The rectangular furnace (2.2m x 3 m) was located at the southwestern end, mirroring the position of the second kiln. The combustion tub was similarly narrow as in the other kiln (40-50cm). On the eastern side, a small square vestibule was created out of bricks. Next to it was another bricked elevated floor, created to be another working area. Post-holes were found in the southeastern corner. One of them contained quartz pebbles. The fourth room (6.8 m x 6.7 m) was the last room to the north. This was connected to the third room but had similarities with the first. It was the only room without a brick floor and its floor was lower than the others. The ovoid furnace (3 m) stood in the middle of this room (Figure 52). It was oriented northwest-southeast. A brick line lead from its eastern opening. The foundation of its outer part was made of larger bricks, while the inner wall, the combustion tube and remains of the vault were made from smaller refractory bricks. The combustion tube had openings on both sides, but three andesitic stone closed it on its southeastern end. This opening could be only have been used in an earlier period because it was 30 cm lower than the level of the combustion tube. The bottom of the firebox had a basin-shaped, hard-packed clay surface. It was covered with a thick glass residue with an ash layer on it. In the foreground of the firebox's southeastern opening lay a trapezoid-shaped ash pit with a working area constructed out of bricks (Figure 53). All the rooms had glass residue, half-finished products, curved bricks, fragments of finished products, pieces of melting pots, ash and even iron tools such as fragments of blowpipes. [178] Orsolya Mészáros argues that the workshop complex had closer parallels with southern workshop types and that the ovoid furnaces were multi-chambered, glass-blowing furnaces. In the fourth room, the bricks of the ovoid kiln were heavily burnt and parts of the combustion tunnel were covered in glass residue.

[178] Mészáros, 679–83.

This indicates that this furnace could be heated up to an extremely high temperature, possibly around 1000°C. Orsolya Mészáros proposes that the firebox and the working chamber above it opened into each other, as described in the works of Parigini, Agricola, Biringuccio and other Italian glass working masters.[179] The rectangular kilns in the middle rooms could have been used as annealing furnaces. This idea is supported by the structure of these kilns. Their working chambers could not have been heated up to high temperatures because the fire chamber was not below the working chamber but next to it. And the surface of the working chamber was around 1.8 m x 2.6 m. [180]

Since the Visegrád workshop was established in the middle of a growing town and founded inside a stone building, it can be compared to the Corinthian workshops. These workshops were established in the northeastern and southern part of Corinth in the thirteenth to fourteenth century close to several smithies and pottery workshops. But the similarities end there, because the southern workshop had an elongated furnace and raw materials found scattered around it.[181] Another workshop established inside a stone building is located near Gambassi, in Germagnana, but that workshop mostly produced half-finished materials, frits, to sell them to other workshops.[182]

The question of typology

Traditionally there are two types of glass workshops found in the literature: the southern and the northern type of glass workshop. There is no question that this division is accurate

[179] Mészáros, 684–85; Mészáros, "Egy 15. századi toszkán üvegműhely," 236–39; Biringuccio, *De La Pirotechnia*; Georgius Agricola, *De Re Metallica*, trans. Herbert Hoover (Eastford: Martino Fine Books, 2014), 574–76.

[180] Mészáros, "15. századi üvegműhely Visegrádon," 687–88.

[181] Kurzmann, *Mittelalterliche Glastechnologie*, 77–79.

[182] Kurzmann, 89–90.

based on the differing glassmaking technologies. The southern type of workshops obtained their alkali flux, the ashes of salt-tolerant plants, from great distances, from the Mediterranean. It provided a cleaner appearing glass than the northern workshops could produce from wood ash. The glass they produced glass had a higher potassium level, thus, their products are often called potash glass.[183] The problematic part of this typology lies in the description and strict classification of the workshop structures.

The southern or venetian-style glass workshop is usually described as having an ovoid or round furnace, which is multi-leveled. This two- or three-story kiln had a combustion chamber in its lower part. A working compartment was established on top of that from ledge or shelf. In this way, the combustion chamber was open to the working area. The working compartment had four to eight openings, depending on the size of the furnace. Frequently, another level was created on top of the working chamber. This smaller compartment served as an annealing furnace for cooling down the products gradually. If the third story was missing, in some cases, they built a brick or stone closed structure close to the top of the kiln that still received sufficient heat to function as an annealing furnace. [184] But this structure was also described as a firewood dryer and storage by Parigini.[185] The other type of furnace in this workshop was a smaller, melting furnace which produced the frits used in the glassblowing kiln. The melting furnace consisted of a lower firebox and an upper, closed working area. This type of workshop would have been commoner in Italy and the Mediterranean. The Venetian type workshop was described by Biringuccio, Parigini, Agricola and Neri.[186]

The northern type of glass workshops had a main furnace with a fire chamber and on top of that a working compartment. The subsidiary furnaces, like the annealing kilns, could be built

[183] Fórizs, "Glassmaking in Hungary from the beginning to the 18th century," 114–15.
[184] Charleston, "Glass Furnaces through the Ages," figs. 12–13.
[185] Mészáros, "Egy 15. századi toszkán üvegműhely," 226.
[186] Charleston, "Glass Furnaces through the Ages," 10–20; Biringuccio, *De La Pirotechnia*; Mészáros, "Egy 15. századi toszkán üvegműhely"; Agricola, *De Re Metallica*, 1950; Dolbashian, "Antonio Neri, L' Arte Vetraria, 1612."

together with it, only separated by a wall or they could built near to it. If they were built together, the annealing part of the kiln did not have a combustion chamber below its working area as it only used the heat from the main furnace. If the annealing kiln was built separately, it had a firebox and a flat working area on top of that. According to Charleston, this type of glass workshop tended to have rectangular or elongated furnaces. The northern type of glass workshop was described by Theophilus, Agricola, Neri and can be seen on the manuscript miniature of Sir John Mandeville"s Travels.[187] The northern type of glass workshops was found in the forests of Bohemia, Germany, England, Hungary and Sweden.[188]

As the part of his typology, Robert J. Charleston theorized that the round furnaces were more common and used in the Venetian-type workshop, while the Northern-type of workshops tend to have elongated or rectangular furnaces.[189] The different furnace shapes had to do more with function than simply conforming to the area where the workshop was constructed. Rectangular or elongated furnaces were described as fritting, melting furnaces and annealing kilns for window glassmaking.[190] The glass workshop in Germagnana should belong to the Southern type, but it possessed a rectangle lime burning kiln, which was previously used as a melting furnace.[191] In Corinth, the southern workshop only has a rectangular furnace. Raw materials for glassmaking were found around this furnace and it seems that Italian masters worked here in the 1thirteenth to fourteenth centuries.[192] In Diósjenő, which should be a

[187] Charleston, "Glass Furnaces through the Ages," 20–28; Theophilus, *On Divers Arts*; Agricola, *De Re Metallica*, 1950; Dolbashian, "Antonio Neri, L' Arte Vetraria, 1612."

[188] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 243; Charleston, "Glass Furnaces through the Ages," 22–23.

[189] Charleston, "Glass Furnaces through the Ages," 11,23; H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 73.

[190] Theophilus, *On Divers Arts*, 49–50.

[191] Kurzmann, *Mittelalterliche Glastechnologie*, 89–90.

[192] Kurzmann, 77–79.

Northern type, workshop II only has two small, round furnaces and a storage building located in their vicinity.[193]

There is a tendency in the Hungarian Kingdom that glass workshops in the Middle Ages were more commonly established in forested areas, as the description of the Northern type workshop suggests (Table 4, Figure 54). It only adds to the picture that most of these workshops were founded close to towns or precious metal mines such as like Sklené Teplice, Glashütten bei Schlaining, Banská Bystrica, Banská Štiavnica, Kremnica and, Krensdorf etc. This location could affect them in many ways, but the most visible one was that they certainly produced glass vessels for gold separation. Fewer of the glass workshops were built in towns, for example: Buda-Felhévíz, Visegrád-Fő Street, Visegrád-Rév Street and, Zagreb. Whether these workshops were royal, noble or citizen-owned, they similarly depended on their connections to get firewood, raw materials, pottery, and iron tools. (Table 5, Figure 55) The monastic owned glass workshops should be also mentioned here. They tend to be more separate and selfsustained than the ones found in town, but they also relied on their connections and, more importantly, they were the part of the monastic order's economic organization. The location of the workshops differed based on the monastic orders' ownership. In the Hungarian Kingdom, only four monastic glass workshops are known so far (Table 6). The two workshops of the Pauline order were established in forests (Budaszentlőrinc and Diósgyőr-Majláth) while the only known workshop in a Cistercian grange at Pomáz-Nagykovácsi operated in the Pilis Forest. Only one workshop, namely the one in Pásztó, owned by the Benedictine order was founded within a settlement. Their main product was commonly window glass for their building projects and for selling; but they also produced glass vessels, bottles, goblets etc.

[193] Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 659.

According to this typology, the medieval workshops in the Hungarian Kingdom should follow the Northern type, but with a more detailed inspection of the excavated sites, it seems that only glass workshops I and III near Diósjenő match the description well. They were constructed in the forest, produced forest glass and were relocated as the woodland was depleted.[194] The other workshops differ from the forest glass workshops in their locations, layout or even their products. The workshop in Pomáz-Nagykovácsi was built in the forest and had a rectangular annealing furnace, but it was established as the part of the Cistercian grange and the glassmaking took place inside stone buildings. Traces of kilns were found in the chapel itself.[195] In contrast, the other monastic-owned glass workshop in Pásztó, was established in the settlement within a stone building.[196] Above all, the workshop complex established in Visegrád, at 5 Rév Street had more similarities with the Southern-type of workshop, but with some Northern-type influence so it could be categorized within both workshop types. The glass workshops were established in the same stone building. The ovoid glass blowing furnaces, with their double walling at the base, suggest that this was a vaulted, two-or three-story kiln, similar to a Southern type of furnace. But the other rectangular annealing furnaces are described as typical Northern-type kilns. Furthermore, Orsolya Mészáros analyzed the works of Agricola, Biringuccio, Parigini and Neri; and based on those writings suggests that the ovoid furnaces, may have had an annealing kiln in their top parts. The workshop would have needed more furnaces, however, to gradually cool down the finished products, thus, they had to establish separate rectangular annealing kilns.[197]

Taken all together, the limited written sources and few excavated medieval glass workshops in the Hungarian Kingdom display both the Southern - (Venetian) type and Northern - (forest) type workshop classifications. Certain tendencies can be observed based on the glass

[194] Mester, *Középkori üvegek [Medieval glasses]*, 10.
[195] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 240–41.
[196] Valter, "Glass workshop and smithy in Pásztó." 203-4.
[197] Mészáros, "15. századi üvegműhely Visegrádon," 684–85.

workshop's location, environment, the owner, and type of products. Generally, however, it can be said that every glass workshop had its own unique construction with structures adapted to serving local requirements in the environment. Considerably more research and field work will need to be done to understand better how glass workshops operated in different areas or environments.

Conclusions

While the previous chapter contains my evaluation of the written sources and information from the non-destructive surveys that have been conducted, this part of the thesis reviewed the few glass workshops that have been excavated. After discussing their features, the chapter analyzed the palace of these glassworks in the traditional glass workshop typology.

The detailed description of these medieval glass workshops was necessary because they provide in-depth information about the structure of the workshops and kilns. Due to the fact, that only four of the workshops have been excavated, one must be careful about drawing general conclusions. However, it is likely that the previous classification system that described typical Southern and Northern workshops, does not consider the workshops tendency to adapt to the requirements imposed by immediate environment. The workshops in Hungary generally fall into the category of the Northern workshop type, based on the type of glass (forest or potash glass) they produced. However, the traditionally described attributes and structures fit them less well. It would seem that all workshops had their own unique structure based on their particular situations. They could be described more accurately as comprised of three heaps of information overlapping in the middle. These "heaps" are location, function, and the social status of their founder.

In the next chapter, I will present a more detailed account describing the needs of the medieval glass workshops. These requirements consist of raw materials, ash, bricks, firewood, pottery, and iron tools etc. All the glass workshops acquired these from their adjacent vicinity which is why they are referred to as installation factors.

Chapter 4 - Installation factors of glass workshops

Introduction

This chapter seeks to examine the reasons behind the site selection factors involved in establishing a glass workshop. The conditions of melting and processing and the properties of the finished products, such as color, were determined by the quality and contamination of the raw materials, which was greatly influenced by the geographical location of the workshops. A continuous supply of firewood and water was crucial to a glasswork's everyday functioning (Figure 56). However, the written sources on the choice of location are scanty and they suggest that it was worthwhile to obtain the cleaner and better-quality raw materials (sand, alkali flux) from far-away locations. In the Carpathian Basin, local materials were more often exploited. This chapter has been divided into five parts. The first part considers the source and types of raw materials used in the workshops. The following part searches for the sources for the firewood and the daily water supply. The last two sections primarily seek to understand the connection between roads and other crafts to the glass workshops.

Raw materials

The main difference between the glassmaking process in the manufacture of luxury versus forest glass was that the Italian workshops imported their raw materials from a distance, while the northern glass workshops used local ingredients and sometimes even remelted broken glass.

The primary ingredient of glass is fine-grained sand with a high quartz content. If clean sand was not available, the glass workers prepared the quartz by heating pebbles and throwing

them into cold water to fragment them. In order to obtain fine grained quartz, they put the blown-up pebble fragments to a grinding mill.[198] A raw material, sand deposit has been found in only one case so far in Schönbuch, where a pit was used to mine sand for the glass workshop at the site.[199] At the Visegrád – 5 Rév Street workshop complex, in room three, a few quartz pebbles were unearthed in a post-hole near to the rectangular furnace. However, they were possibly found in a secondary position.[200] Orsolya Mészáros suggests that primary melting, raw-glassmaking did not take place in the workshops at Rév Street.[201] Nevertheless, if the glass workers made raw glass or frits, it is very likely that they got the silica from the river gravel or sand from the Danube which flows only a 100 m away from the workshop.[202] Based on the chemical analysis of the glass from the glass workshops at Diósjenő, the glass was not made of quartz sand but rather from feldspathic sand. The nearest occurrence of this feldspathic sand is on the northeastern border of Diósjenő.[203] The silica component of glass from the workshop at Pásztó could have been made of quartz sand, feldspathic sands or from pebbles (so-called frog sand, *békasó*). However, the samples analyzed from Pásztó and Visegrád- Fő Street could not confirm the sources of the quartz that was used.[204] A record from 1703 also suggests that the later glass workshop near Pilisszentlélek obtained the sand they needed from the near vicinity. András Hutás, a master glassmaker from Pilisszentlélek, mined the quartz in the nearby Csipke valley, at the foot of Lencse hill.[205] In the case of the Pomáz glass workshop, the Danube could have served as a sand or gravel deposit. The the area around the Rómaifürdő

[198] Kurzmann, *Mittelalterliche Glastechnologie*, 31–32.

[199] Frommer and Kottmann, *Die Glashütte Glaswasen im Schönbuch. Produktionsprozesse, Infrastruktur und Arbeitsalltag eines spätmittelalterlichen Betriebs*, 69.

[200] Mészáros, "15. századi üvegműhely Visegrádon," 681–82.

[201] Mészáros, 684–85.

[202] Orsolya Mészáros, "Visegrád késő középkori város története és helyrajza [The History and Topography of the Late Medieval Visegrád]" (Doctoral Dissertation, Debrecen, Debreceni Egyetem, 2008), 97.

[203] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 89; Mester, *Középkori üvegek*, 158.

[204] Mester, *Középkori üvegek*, 36–45.

[205] Pál Dobay, "A pilisi üveggyártás [Glassmaking in the Pilis]," *Erdészeti lapok* 2, no. CXLVIII (2013): 59.

(Roman Bath near the Danube) may also have served as a source for the raw ingredients. The quartz material could also have been quarried elsewhere nearby since sand deposits could still be found in places like Pilisborosjenő, Csobánka and, Üröm, in the valley of Dera Brook and in the Holdvilág trench.[206]

Agricola and Parigini also mention the importance of fine grinding the quartz.[207] The importance of these grinding mills appear in other written sources as in the case of Antonius Italicus, glassmaker. He acquired the mill of the Poor Clares of Óbuda and used it to grind raw materials for his workshop at Felhévíz. However, this mill was equally important to the Poor Clares and they made great efforts to get back their former mills before finally they agreed to lease the mill to Antonius.[208] A document from 1331, issued in Kremnica, also lists a good number of mills close near to the mining town and Sklené.[209] It is likely that the glass workshops at Kremnica and Sklené used some of these mills to grind their pebbles into fine grained quartz. Near Pomáz, the Pilis Abbey possessed several mills, one of which, for example, powered the bellows and hammer mill of the metalworking workshop and there were several other mills located between Kovácsi and the abbey. However, as yet, there is no evidence that any of these were used by the glaziers.[210] Near the abbey at Pásztó runs the Malom Brook (Mill brook), which according to Ilona Valter, provided the water need for the glass production there as well as the energy needed for the water mill to grind the raw materials.[211]

[206] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 20–21.

[207] Agricola, *De Re Metallica*, 2014, 572; Mészáros, "Egy 15. századi toszkán üvegműhely," 228.

[208] H. Gyürky, "The Use of Glass in Medieval Hungary," 77–78; András Vadas, "Who Stole the Water? The Control and Appropriation of Water Resources in Medieval Hungary" (Doctoral Dissertation, Budapest, Central European University, 2020), 100.

[209] Vadas, "Water Resources in Medieval Hungary," 142–43.

[210] Elek Benkő, "Fémfeldolgozás a középkorban. [Metalworking in the Middle Ages]," in *A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 691–708; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 29.

[211] Valter, "Glass workshop and smithy in Pásztó," 219.

To lower the melting point of the silica, medieval glassworkers used different types of alkali flux. From Roman times to the eighth century, mineral natron was the most common flux although its use in the Middle Ages is rare.[212] Interestingly, the chemical analysis on the glass samples from Pásztó showed that mineral natron was used as flux to produce those glass products.[213] The possible explanation for this could be that the mineral natron they used derived from the Balkan Peninsula or Hungary's salt lakes. However, there are no records on use of the former for this purpose.[214] A more commonly used alkali flux in medieval glassmaking was derived from the ashes of salt-tolerant plants. It was produced in the Mediterranean and widely used in Syria, Italy, and South France.[215] The development of Venetian glassmaking from the 1280s onwards was based on the use of special, high-quality Syrian ash. Venice also sought to restrict trade in ash of salt-tolerant plants. Nevertheless, other glassmaking centers in Italy and north of the Alps were also able to obtain good quality sodium-containing fluxes.[216]

Based on the samples analyzed from the Diósjenő workshop, the ash used in this glass production center was imported from the coast of Asia Minor or the Spanish coast.[217] Unfortunately, further research and the interpretation of the chemical analysis is needed for the glass from Pomáz- Nagykovácsi as well as the workshops at Visegrád to identify the type of alkali flux used and where it came from.[218]

[212] Kurzmann, *Mittelalterliche Glastechnologie*, 34.

[213] Valter, "Adatok a pásztói monostor gazdasági életéhez [Details of the economic life of the monastery of Pásztó]," 429; Valter, "Glass workshop and smithy in Pásztó," 221–24.

[214] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 22.

[215] Kurzmann, *Mittelalterliche Glastechnologie*, 34; Fórizs, "Glassmaking in Hungary from the beginning to the 18th century," 115–16.

[216] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 23.

[217] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 77; Mester, "Research of medieval glass vessels and glasshousdes in Hungary," 61.

[218] Anežka Černá, "Pomáz a Visegrád Analízis" (MA Thesis, Praha, Vysoká škola chemicko-technologická v Praze, 2015).

Forest glass or potash glass making was defined by the potassium-containing wood ash used as alkali flux. The potassium levels depended on the plant species. Theophilus suggested the use of thoroughly dried beech wood ash, while Agricola mentioned the ashes of oak or pine trees. The tree types may differ, but the two authors agree on the importance of clean ashes.[219] There is also evidence that glass workshops occasionally bought domestic or industrial ashes, although the quality of this product may have been questionable.[220] In Plainer (South France) close to the furnaces, a thick layer of ash was identified as the source of alkali flux for the glass products.[221] No similar phenomena was found in the workshop complex at Visegrád, Rév Street. On the other hand, at Pomáz-Nagykovácsi, the ash deposits that were found in the chapel could have had some connection to the nearby furnaces.[222] Similarly at Pásztó, a thick layer of ash was found close to the furnace in the second room of the first building.[223]

The glass workshops tend to reheat and reuse or buy broken glass as flux. Fragments of aVenetian prunted glass was discovered in Hungary, close to workshop I at Diósjenő. This find suggests that the workshop also used broken, imported glass to lower the melting temperature of the quartz.[224] Similar fragments of reused glass were found at the Pomáz site.[225]

As the alkali fluxes reduced the chemical stability of glass, more calcium was needed to stabilize the material. This third component was only necessary when the ingredients were purified and had lost their natural calcium. Karl Hans Wedepohl has conducted an examination on medieval glass from Germany and concluded that the composition of the glass determined whether lime had to be added to the glass mixture. If they it was necessary then the CaO/ K2O ratio was 2.3-2.7, if not, the ratio was less than 1. He established an approximate chronology

[219] Theophilus, *On Divers Arts*, 61, 59; Agricola, *De Re Metallica*, 2014, 573.
[220] Kurzmann, *Mittelalterliche Glastechnologie*, 35.
[221] Kurzmann, 88.
[222] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 24.
[223] Valter, "Glass workshop and smithy in Pásztó," 203.
[224] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 76.
[225] Laszlovszky and Stark, "Medieval Glass Production at Pomáz-Nagykovácsi," 254.

for glass workshops from north to south Germany based on this.[226] However, in Hungary, the use of calcium seems to be a workshop specific phenomenon rather than the consequence of the technological process. [227]

Firewood

A regular, dependable supply of wood was crucial to the smooth operation of a glass workshop, not just as an alkali flux but also as firewood. Thus, it is not surprising that most workshops were established in proximity to woodland (Figure 57).

In Germany, it is common to see a number of huts of nearly the same age, located only a few kilometers apart from each other. The relocation is explained by the fact that glaziers tended to move after they depleted the surrounding forest. This situation has also been demonstrated for Hungarian glass workshops but in the eighteenth century (for example Óhuta, Újhuta, etc.).[228] The extent of deforestation caused by glass production is illustrated by Karl Hans Wedepohl: the potassium content of dry beech wood is 0.1%, the forest glass's potassium content is generally around 19%, which means that to produce 1kg of glass, 190 kg of wood is needed for the raw materials. Furthermore, adding the fuel used to heat the kilns to this number, 1 kg of glass produced would have required the burning of a total of about 250kg of wood. If a glass workshop produced 10-15 tons glass per year, it would have needed cc. 2500-3250 tons of wood, meaning that 10-15km^2 of forest could be burnt each year. Based on the amount of wood that could be burnt, the lifespan of a glassworks located in the Black Forest was estimated to be between 6-20 years.[229]

[226] Karl Hans Wedepohl, *Mittelalterliches Glas in Mitteleuropa: Zusammensetzung, Herstellung, Rohstoffe*, Mathematischphysikalische Klasse 1 (Göttingen: Vandenhoeck & Ruprecht, 1998), 15–25.

[227] Fórizs, "Glassmaking in Hungary from the beginning to the 18th century," 125.

[228] Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 663–64.

[229] Wedepohl, *Mittelalterliches Glas in Mitteleuropa: Zusammensetzung, Herstellung, Rohstoffe*, 44–46.

The intense depletion of the forests led to strict regulation of woodland use in Europe from the fourteenth to fifteenth centuries, known as forest laws. In 1340, Louis IV and in 1355 Charles IV banned the use of imperial forests around Nuremberg for glassmaking. In 1570, Emperor Nicholas II prohibited the establishment of glass workshops in the royal forests of Bohemia.[230] The guild letters of Spessart (1406) and Hesse (1537, 1559) regulated the amount of glass that could be produced weekly or yearly. They even determined the number of workers, the tools and equipment that could be used and the training time of a glassmaker. Besides the annual rent they had to pay for the use of woodland, glass workshops had to supply window glass and other glassware to the owner of the forest.[231]

In Hungary, the location of the glass workshops is closely linked to the continuous beech forests that represent the natural vegetation cover of our 400-600m mid-mountain ranges.[232]

The royal forest of Pilis falls into this category and had at least three glass workshop complexes located within it and possibly even more. However, Pilis was mentioned as the king's private woodland in 1187, where he hunted. This territory was also referred to as *predia* which was an allodial, that is, privately held estates that were managed by servants. And the leader of such a unit was called procurator.[233] This special legal role is reflected in the former settlement network of the area, as there are no private castles in the mountains and only a few villages with forestry and logging functions were established on the edge of the area of the royal forest. The only exception to this were the royal complexes, centers and the ecclesiastic

[230] Wedepohl, 44–46; Péter Szabó, *Woodland and Forests in Medieval Hungary* (Oxford: Archaeopress, 2005), 20–24.

[231] Werner Loibl, "Historische Voraussetzungen Und Technologische Bedingungen Der Spessarter Glasmacherordnung von 1406," in *Glashüttenlandschaft Europa. Beträge Zum 3. Internationalen Glassymposium*, ed. Helmut von Flachenecker, Gerrit Himmelsbach, and Peter Steppuhn (Regensburg: Schnell & Steiner, 2008), 56–63; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 30.

[232] Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 657; László Szende, "Crafts in Medieval Hungary," in *The Economy of Medieval Hungary*, ed. József Laszlovszky, Balázs Nagy, and András Vadas, East Central and Eastern Europe in the Middle Ages, 450–1450 49 (Leiden - Boston: Brill, 2018), 391.

[233] Szabó, *Woodland and Forests in Medieval Hungary*, 89.

institutions founded by the royal family such as the Pilis Abbey. Although the legal regulations on the Pilis forest area have not survived, they certainly played an important role in the development of the glass workshops in Visegrád and Pásztó.[234]. In the case of the workshops in Visegrád - Fő Street and Rév Street, founders exploited the geographical conditions of the territory. The workshops were located on the lower, southern part of the town and possibly received their wood supply from the higher up, northern woodlands.[235] The other excavated workshops were also established near to or in the forest. The glass workshop at Pásztó acquired its wood supply from the beech forests of the Mátra.[236] The workshop in Börzsöny, near Diósjenő, had to relocate due to their growing need for beech and other types of wood. Thus, the three workshops were actually located relatively close to each other.[237]

Water supply

Water was essential for almost every stage of the glass manufacturing process. It was needed to clean the raw materials, to keep the wooden tools moist, to cool down the hot tools such as glass-blowing pipes, pontils and, iron rods. And if the workshop made its own bricks and pottery, water was also necessary for that work. Water was equally important to supply drinking water for the workers and deep, running water could play an important role in the transport of the finished products or raw materials.[238]

Therefore, it is not surprising that all of the excavated glass workshops - and those we have substantial information about - had at least one water source recorded as being located near to them.

[234] Ferenczi, László and József Laszlovszky, "Középkori utak és határhasználat a pilisi apátság területén [Medieval roads and boundary use in the Pilis Abbey area]," *Studia Comitatensia. A Ferenczy Múzeum Évkönyve*, no. 1 (2014): 103–6; Szabó, *Woodland and Forests in Medieval Hungary*, 109, 89.

[235] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 28.

[236] Valter, "Glass workshop and smithy in Pásztó," 219.

[237] Mester, *Középkori üvegek [Medieval glasses]*, 10.

[238] Kurzmann, *Mittelalterliche Glastechnologie*, 46.

In Visegrád, the main topographic element of the town was the main road running parallel to the Danube. The road, as it does today, ran slightly inland from the Danube. The stream running down from the hills (today Apátkúti, in the Middle Ages it was probably called St George's Brook), ran along a different line from the path it takes today as it turned sharply southwards as it entered the town, running parallel to the Danube for a while before flowing into it. [239] The brook and the Danube River alone would have been sufficient as source of water but the workshop at 5 Rév Street seems to had its own well as well. The well has not yet been excavated yet. [240]

At Pomáz-Nagykovácsi puszta there may have been a well in the courtyard, the nearest being 20-30 m from the building complex and a small watercourse (named Salabasina). Near to the glass workshop runs the Dera Brook and, above all, the granges had fishponds, dams and channels. It is likely that the craftsmen in the workshop only needed to use the well and the nearby brook for industrial purposes. [241] In a like manner, workshop I in Diósjenő lay close to its own brook which is still called Kemence patak in Hungarian or Furnace Brook in English even today. Workshop II even had its own water source called the Üveghuta kútja, which translates as the well of the glassworkshop.[242] In Pásztó, the Kövicses (with pebbles) Stream, flowing from the Mátra hills was led to the eastern side of the Benedictine abbey to provide water for the workshops, the mill and the monks. It was even given a different name in this section: Malom patak (Mill Brook).[243] Fiscal records from the sixteenth century (1514, 1526, 1536) from Râșnov preserved the Üveges (glassmaker) and Glaser family names, who operated

[239] Mészáros, "Visegrád késő középkori város története és helyrajza," 81.
[240] Mészáros, "15. századi üvegműhely Visegrádon," 677.
[241] Laszlovszky, "Ciszterci vagy pálos? A Pomáz-Nagykovácsi-Pusztán található középkori épületmaradványok azonosítása [Cistercian or Pauline? Identification of the Medieval Architectural Remains Located at Pilis-Nagykovácsi-puszta]," 297–98; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 29.
[242] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 69.
[243] Valter, "Glass workshop and smithy in Pásztó," 219.

glass workshops near to the settlement. Their possible water source could have been the closest brook called Üvegcsűr (Glass workshop Brook).[244]

Roads

The role of roads was crucial to the life of the glass workshops. It is for this reason that workshops were not established too deep in the forests (Figure 58). The workshops received their wood supply, iron tools, food for the workers, raw materials such as sand, ash and, clay via roads. And they could distribute their finished products to the markets through roads.

In the Middle Ages, as today, there were two main roads leading from Buda to Esztergom, one of which ran via Óbuda- Solymár- Piliscsaba- Dorog to Vienna, roughly the same as today's main Route 10 (10-es főút). The other road, running along the Danube, was oriented slightly inland from the coast, like today's main Route 11 (11-es főút), passing north of Óbuda through Pomáz, then through Szentendre and Bogdány, Visegrád, the Sibrik hill and Alsóvár to Esztergom.[245] This meant that the finished glass products from the workshops at Fő and Rév Streets could easily reach larger markets, royal and noble estates, towns and settlements.

Elek Benkő pointed out that the monastery of Pilisszentkereszt, which was apparently in a secluded location, was in fact connected by a dense network of roads to its nearby and more distant estates, the sand and stone quarries of the area, Pilisszántó, Csobanka, the Holdvilág trench and Dobogókő.[246]

An important medieval road branches off from the main road along the Danube. It runs along the Dera Brook, passing through Pomáz and several later deserted settlements, such as

[244] Csiffáry, *Magyarország üvegipara 1920-ig*, 79.

[245] Benkő Elek, "Via regis, via gregis. Középkori utak a Pilisben. [Via regis, via gregis. Medieval roads in the Pilis]," in *„Fél évszázad terepen". Tanulmánykötet Torma István tiszteletére 70. születésnapja alkalmából*, ed. Miklós Zsuzsa and Kővári Klára (Budapest: Magyar Tudományos Akadémia Régészeti Intézete, 2011), 115–19; Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 31.

[246] Benkő, "Középkori utak a Pilisben," 115–19.

Kovácsi. This road branched off at Aszófő, passing the Pauline monastery of Pilisszentlászló, in the direction of Visegrád. [247] Zsuzsa Pető, in her analysis of the internal roads within the Pilis used the LCP (Least Cost Path) method to demonstrate that people probably followed the most economical route in terms of energy consumption between medieval settlements and centers in the Pilis area, routes which did not always coincide with the paths of Roman roads. [248] This shows, that the Cistercian grange at Pomáz-Nagykovácsi was a part of a lively road network.

Unfortunately, we have less information about the medieval roads connected to the hree workshops in the woodland of Börzsöny although it is certain that Workshop I was found between two diverging dirt roads. There is not enough information available, however, to date these roads properly.[249] We also have limited data about the roads around the glass workshop at Pásztó. There should have been at least one main road connecting Hatvan – Pásztó – Hollókő and Szécsény.

Connections with other crafts

A glass workshop could only produce glassware if it functioned as a hub, bringing together other crafts (Figure 59). A glass workshop needed a continuous supply of raw materials but also clay or refractory crucibles, bricks and iron tools. Thus, it required close connections with potteries and smithies.

The building elements in the furnaces and crucibles were made of the same special refractory clay, making it economical and advantageous to produce them locally, especially in such large quantities. However, this fire-clay had to endure more than 1200°C in the kilns, and

[247] Ferenczi, László and Laszlovszky, "Középkori utak és határhasználat a pilisi apátság területén [Medieval roads and boundary use in the Pilis Abbey area]," 103–6.

[248] Zsuzsa Eszter Pető, "Római vagy középkori? Történeti utak a Pilisben. [Roman or medieval? Historical roads in the Pilis]," *Magyar Régészet Online Magazin*, no. Ősz (2014): 2–7.

[249] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 69–71.

such material not readily available everywhere. In England there is evidence that fire resistant clay was regularly transported to glass workshops from a distance. The best refractory clay came from Worcestershire. A chemical analysis showed that the crucibles in Herefords were made from that clay.[250] Unfortunately, the Hungarian research so far lacks information on the location of the best fire-resistant clay in the Carpathian basin. However high-quality building ceramics and floor tiles were produced at high temperatures near the Abbey of Pilis. Thus, it is also possible that the right source of clay was available there. Combined with the right firing technology, the workshop at Pomáz could get its bricks and crucibles from close by.[251]

Smithing was also vitally important for the process of glassmaking, because the iron tools such as glassblowing pipes and pontils needed to be replaced frequently. Therefore, in Pásztó and Pomáz it was practical that a blacksmith operated quite close to the workshops. In the case of Pásztó, the smithy was established in the building next to the glass workshop. Inin the case of Pomáz, the smithy was presumably located closer to the Dera Brook, in the village of Kovácsi (blacksmith).[252] At the same time, we have no evidence that the glass production at Pomáz-Nagykovácsi was chronologically parallel to the iron production. Therefore, it is possible, that the iron tools for the glassmakers were produced in the metal production center of the Pilis Abbey, at a distance of only four kilometers from the monastic grange at Kovácsi. In Visegrád, there are written sources concerning a blacksmith named János from 1360. He lived in either Fő or Szűk Street close to both excavated glass workshops.[253]

Unlike the previously discussed crafts, glassmaking was not dependent on the mines. However, mines used glass vessels in which to separate gold from other metals.[254] For instance,

[250] Charleston, "Vessel Glass," 240.
[251] Megyeri, "Üvegleletek a visegrádi és a pomázi üvegműhelyekből," 34.
[252] Valter, "Glass workshop and smithy in Pásztó," 216; Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains," 2.
[253] Mészáros, "Visegrád késő középkori város története és helyrajza," 78.
[254] Zoltán Batizi, "Mining in Medieval Hungary," in *The Economy of Medieval Hungary*, ed. József Laszlovszky, Balázs Nagy, and András Vadas, East Central and Eastern Europe in the Middle Ages, 450–1450 49 (Leiden - Boston: Brill, 2018), 179.

in Banská Štiavnica, the same master, Sebestyén Schmelczer separated gold and operated the nearest glass workshop. He received 20 forints yearly to supply the mine with glass vessels.[255] The litigation cases from Sklenó Teplice also show the glassworks had important connections to precious metal mining and minting. [256]

Conclusion

The aim of this chapter was to discuss and analyze the detailed installation factors critical to the smooth running of a medieval glass workshop in Hungary. The water and wood supply seems to have been the key factor in choosing a location to establish a workshop. Water was needed daily, not only in the glassmaking process but also for life at the site, and for everyday tasks like cooking, cleaning etc. Some of the workshops mentioned here had more than one water source near to them, like Pomáz-Nagykovácsi or the workshops at Visegrád. Wood was used for building material, firewood, and its ashes for alkali flux. Glassmaking itself required great amounts of wood and could easily deplete large forest areas in a relatively short period so rulers, landowners and guilds strictly regulated the glassmakers' work.

Access to the raw ingredients was also a critical operating factor. The basic material for glass, quartz, was mainly extracted from sand pebbles. But before melting, the pebbles had to be cleaned and ground in some way. Based on the sources, the glassworkers mostly used near by watermills for this purpose, like Antonius master when he occupied the Poor Clare's mill at Buda-Felhévíz. The quartz's melting temperature had to be lowered with some kind of alkali flux. Different types of alkali fluxes existed such as mineral natron, ash from salt-tolerant plants and ash from beech wood. The samples from Diósjenő showed that the workshop used

[255] Csiffáry, *Magyarország üvegipara 1920-ig*, 75.

[256] Csiffáry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 125–26; Csiffáry, *Magyarország üvegipara 1920-ig*, 61–62.

imported ash, made from salt-tolerant plants. It was the same type of alkali material that the Venetian glass workshops used. Unfortunately, glass samples from the other excavated workshops are yet to be analyzed.

Another factor in successful operations was the presence of a good road network along which a workshop could access refractory clay or bricks and crucibles from potteries. The supply and replacement of the used iron tools were also important, hence a glass workshop needed reliable links to a smithy. This could explain the fact, that for example at Pásztó, the glass workshop was established right next to a blacksmith.

An additional factor affecting location was the proximity of precious metal mines. In this case, the mine required glass vessels from the nearest workshop to separate gold from other metals. This explains the fact that at least one workshop was established near to mines like Banská Štiavnica and Kremnica.

Chapter 5 – A Glimpse at the Glaziers

A brief look at the life of glassmakers in the Kingdom of Hungary compared to other European countries

Introduction

After exploring the economic and environmental factors and needs of glass workshops in Hungary, this chapter examines the people who were involved in the glassmaking process. The available sources are scarce and therefore paint a somewhat indistinct picture about the social status and everyday life of glassworkers. The glassworkers' operation in Hungary raises a few pertinent questions: How did glassmaking begin in medieval Hungary? How did the glassblowers and their apprentices live and work? In addition to this, as there were different types of workshops - monastic, forest, and urban glass workshops - glassblowers and workshop owners necessarily came from different social strata. The answers to these questions, despite the scarcity of evidence, should provide a small glimpse into the life and work of glass makers in the Kingdom of Hungary.

How did glassmaking begin in the Kingdom of Hungary and where did the first glaziers came from?

The kingdoms and principalities adjacent to Hungary are all known to have had continuous glassmaking activity from early on. As Katalin H. Gyürky suggests, Hungary is

probably no exception.[257] At the same time, both Gyürky and, later, László Veres emphasize the fact that in the beginning, the impact of Byzantine manufacturing and imported products suppressed indigenous glassmaking.[258] Consequently, between the tenth and thirteenth centuries, bottles, beakers and lamps were largely imported into the Kingdom of Hungary. Although there are excavated workshops from the Carolingian period as at Zalavár (Mosaburg) and Nitra from the ninth century, they presumably disappeared before the Hungarians arrived in the territory.[259]

The first excavated glass workshop operated in Pásztó in a Benedictine (later Cistercian) monastery. According to Ilona Valter, the workshop produced window glass in the twelfth and thirteenth centuries, and the structure of the glass workshops was the same as the one's described by Theophilus.[260] This workshop presumably produced glass products only for the monastery and imported products continued to dominate the markets.[261]

In the thirteenth century, the source of imported glass objects changed: they were no longer brought from Byzantium but from Venice. This change was the result of the Fourth Crusade, which was supported by the doge of Venice, Enrico Dandolo. In 1204, the Latins invaded Constantinople and Venice gained control over the oldest glass workshops there and in Syria. They forced some glassmaker masters to move to Venice while some migrated by

[257] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 217.

[258] H. Gyürky, 210; László Veres, *Üvegművesség a 16-19. század [Our Glassworks in the sixteenth - nineteenth century]* (Miskolc: Herman Ottó Múzeum, 2006), 29–30.

[259] Béla Miklós Szőke, "Mosaburg/Zalavár und Pannonien in der Karolingerzeit," *Antaeus* 31 (2010): 9–52;; Béla Miklós Szőke, "A Kárpát-medence a Karoling-korban és a magyar honfoglalás [The Carpatian Basin in the Age of the Carolingians and the Hungarian Conquest]," *MTA BTK MŐT Kiadványok* 1 (2014): 31–42; R.J. Charleston, "Glass Furnaces through the Ages," *Journal of Glass Studies* 20 (1978): 22. Zalavár was an exceptional glass workshop, which made silver-stained and colored glass window pieces. Béla Miklós Szőke, Karl Hans Wedepohl, and Andreas Kronz, "Silver-Stained Windows at Carolingian Zalavár, Mosaburg (Southwestern Hungary)," *Journal of Glass Studies* 46 (2004): 85–104.

[260] Ilona Valter, *Pásztó a középkorban [Pásztó in the Middle Ages]* (Budapest: Metem, 2018), 112; Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban," *Archaeologiai Értesítő* 140 (2015): 219–20.

[261] Csiffáry, *Magyarország üvegipara 1920-ig*, 61–62.

their own free will.[262] From the thirteenth century onwards, these masters produced both tesserae and blew window glass, bottles, goblets, and beakers for export. In 1271, the *Capitolare*, the code of glass workshops, came into force. These regulations forbade the masters to emigrate, to sell raw materials such as salt and frits, or to sell their knowledge of glassmaking. If a master fled from Venice he was immediately sentenced to death and his family inprisoned.[263] Due to the increasing fire risk, in 129, the workshops were relocated to Murano.[264] Despite the serious consequences, the charter evidence attests to an intense wave of emigration in 1295.[265] The glassmakers relocated their workshops to other parts of Italy such as Treriso, Vicenso, Padua, Mantua, Ferrara, Ravenna, Bologna, and Altare, a small settlement near Genova.[266] According to Jaroslaw Vávra, most of the masters who established a workshop in another country came from Altare, where they had a tradition of visiting foreign glass workshops to learn their practices. This was certainly true for France and the Netherlands.[267]

Although imported Venetian products retained their privileged, prestigous place in fourteenth century Hungary, slight changes can be observed. In the first half of the fourteenth century, Italian glassmakers from Murano or another settlement, perhaps Altare, established a glass workshop in Dubrovnik.[268] It became a significant glassmaking center with strong trade connections to Sicily, Apulia and the Balkans. Verena Han convincingly argues that the Venetian glass found in Serbia and Macedonia, was de facto made in Dubrovnik.[269] In the first half of the fifteenth century, names suggesting local Slavic origins, begin to appear in the

[262] Angelika Wesenberg, *Venezianisches Glas 16. bis 18 Jahrhundert aus Museen der DDR. Sonderausstellung des Kunstgewerbemuseums mit Leihgaben aus Museen der DDR im Schloss Köpenick, August bis Oktober 1981*, First edition (Berlin: Staatliche Museen, 1981), 5–6.

[263] Mariacher Giovanni, *Edle Gläser von Der Antike Bis Murano* (München: Bruckmann, 1962), 14–15; Veres, *Üvegművességünk*, 25.

[264] Veres, *Üvegművességünk*, 25.

[265] Astone Gasparetto, *Il vetro di Murano* (Venezia: Generico, 1958), 51.

[266] Veres, *Üvegművességünk*, 25.

[267] Vávra, *Das Glas und die Jahrtausende*, 93–94.

[268] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 213; Verena Han, "The Origin and Style of Medieval Glass Found in the Central Balkans," *Journal of Glass Studies* 17 (1975): 114.

[269] Han, "The Origin and Style of Medieval Glass Found in the Central Balkans," 114.

surviving account books and charters. But in 1440, Dubrovnik became part of the Ottoman realm and a taxpayer to the Sultan. Katalin H. Gyürky suggests that it was at this time that the Italian and indigenous glassmakers sought more peaceful circumstances in other places such as the Kingdom of Hungary.[270]

The glass import from Venice continued uninterrupted until Sigismund of Luxembourg went to war with the state. In 1417, he decreed that the main German towns should end their business connections with Venice. Instead, they were instructed to get their Levantine products in Genova. Sigismund even planned an overland route through Hungary to connect to the Levantine trade.[271] Although this decree was in force only until 1433, the glass market was profoundly affected by this regulation. Moreover, due to the high customs tax the number of glass workshops was halved. The smaller shops closed and the masters emigrated to other countries.[272]

These facts can perhaps shed a dim light on the appearance of Italian glassmakers in the written sources in Hungary. In 1438, a master from Zagreb called Bartholomeus Italicus vitripar asked for compensation because he suffered an attack from Medvedgrad Castle as he was coming back from the market of Ptuj with glassware worth two million florentius.[273] Meanwhile in the same year, Anthonius Italicus vitripar (*factor sue laborator vitrorum*), a citizen of Buda, unlawfully occupied the water mill of the Poor Clares of Óbuda. In the end, the parties were able to agree that master Anthonius would pay rent to the Poor Clares and work for them, if they needed glass products. In return,, the abbess bought silica sand for

[270] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215.

[271] Elemér Mályusz, *Zsigmond király uralma Magyarországon [Sigismund's Reign in Hungary]* (Budapest: Gondolat Könyvkiadó, 1984), 93.

[272] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215.

[273] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 85; H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215.

him.[274] Katalin H. Gyürky argues that the mill was appropriated by the glazier because the river was suitable for cleaning the silica sand, and the mill could be used to grind the raw materials for glassmaking.[275]

There is more archaeological and written evidence about the growing number of glass workshops from the sixteenth century onwards but only a few mentions of the masters' origins. For instance, the glass workshop of Medzev was established by masters from Poland.[276] The workshop in Tălmaciu was built by German and Hungarian glassmakers at the end of the sixteenth century,.[277]

The complicated question of whence glassmaker masters or the knowledge of glassblowing came to Hungary is uncertain. Based on this tentative outline, the movement of products and masters varied in different territories and centuries. While it seems that there was a Venetian impact on glassmaking in Hungary from the fourteenth century onwards, the surviving sources are too scarce to reveal from which part of Italy the masters emigrated. In the fifteenth century it is possible that some came from the Balkans, and in the sixteenth century even from Poland and Germany. Once they settled in the country, they worked together with Hungarian masters.

[274] L. Bernát Kumorovitz, *Budapest történetének okleveles emlékei III. (1382-1439) [The Charters of the History of Budapest]* (Budapest: Budapesti Történeti Múzeum, 1989), no. 1206.

[275] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]," 85; H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215; Csiffáry, *Magyarország üvegipara 1920-ig*, 69; Csiffáry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 132–33.

[276] Csiffáry, *Magyarország üvegipara 1920-ig*, 77.

[277] Csiffáry, 80.

The role of monks and women in glassmaking

Glass workshops can also be classified according their environmental and social context as monastic, forest, royal or town glass workshops. They produced different type of glass products and they certainly had different organizational structures and even furnace types. This also means that the masters and owners had different social backgrounds. In a monastic setting, monks could produce their own glass. Around 1160, a monk, named Gerlachus wrote his name and drew his portrait on the glass window he made for the Premontratensians of Arnstein.[278] In Hungary there are only three workshops connected to monastic orders, these are: Pásztó, Pomáz-Nagykovácsi and Budaszentlőrinc. A certain frater Jacobus fenestripar worked in the Pauline monastery of Budaszentlőrinc. He is known to have made glass windows for the monastery.[279] He even taught the craft to the younger brothers.[280]

The written sources barely differentiate between the owners of the glass workshops, glassblowers, stained-glass makers, and merchants, all of whom appear as *vitripar* or *vitrearius.* There are very few exceptions, for example, a *Jehanne la verriere, marcheande de teiles* is found in the thirteenth-century Parisian tax rolls.[281] Curiously, out of the four women found in the tax rolls, the most successful one is the above mentioned Jehanne. As Meredith Parsons Lillich outlines the role of the four women, they may appear as the owner of the workshop if they were widowed or they were gifted one. They may have been glass painters or merchants; but it is improbable that they were glassblowers, because it was hard physical work.[282] In Hungary, there is one example in which a woman's name appears in connection with a glass workshop. In Bodony, near to the Castle of Eger, lived István Kismester, who

[278] Lillich, "Gothic Glaziers: Monks, Jews, Taxpayers, Bretons, Women," 72.
[279] Gergely Gyöngyösi, *Arcok a magyar történelemből [Vitae fratrum]*, trans. Vince Árva, Béla Csanád, and Ferenc Csonka (Budapest: Szépirodalmi Könyvkiadó, 1983), 240; Csifféry, *Magyarország üvegipara 1920-ig*, 69–70.
[280] Zolnay, *Az elátkozott Buda*, 400.
[281] Lillich, "Gothic Glaziers: Monks, Jews, Taxpayers, Bretons, Women," 78.
[282] Lillich, 80–81.

produced window glass and lamps. When he died in 1506, his widow continued his work. She is known, for example to have finished glazing the window in front of the altar of the Virgin Mary in the church of Eger.[283]

Talkative names

Names connected to glassmaking like *Glaser* or *vitripar*, *vitrearius* began to spread in Hungary in the fourteenth century (Figure 60). Most of the names found in the written sources cannot be traced back precisely to an existing workshop. This is primarily because, to date, only a few workshops have been excavated in Hungary, and the written sources are more fragmented and scantier than those in neighboring countries and beyond.

Although personal names might suggest that a person's profession was connected to glassmaking or selling, in later periods, names could lose their meaning and function as a surname only. However, it seems that the geographical distribution of these family names more or less corresponds to the known glass workshop areas. (Figure 61)

The Glaser surname is mentioned in the 1379 account books of Bratislava. Glaser Laurentius was the founder of the glass workshop at Lehota.[284] Other examples include a "Glaser, filius Gerhardi" at Sklené Teplice and a Peter Glaser at Sklené.[285] While their names can be confidently connected to glassmaking in the region, the Glasers from Bardejov and Râșnov were connected to the profession with less certainty.[286]

The case of the Latin designation *vitripar* seems more straightforward. The name appears in connection with glassmaking at Visegrád *(Johannes vitripar de Wisegrad),* Buda *(Antonius Vitripar Italicus*) Zagreb (*Bartholomeus Italicus vitripar*), Banská Štiavnica, Sibiu

[283] Zolnay, *Kincses Magyarország*, 269; Csiffáry, *Magyarország üvegipara 1920-ig*, 190.
[284] Veres, *Üvegművességünk*, 34.
[285] Csiffáry, *Magyarország üvegipara 1920-ig*, 61–65, 66–67; Csiffáry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 125–26.
[286] Csiffáry, *Magyarország üvegipara 1920-ig*, 77, 79.

and Cluj-Napoca.[287] However, whether they were producing glass or selling it remains an open question.

Day and night in a glass workshop

In 1524, the assistant castellans of Diósgyőr put the following question in their report to castellan Lénárd Gallinczer: "It would be good to know how food is supplied and what is the proper amount of payment for these masters, because they won't tell us."[288] That payment, in food and wine supplies, were critical questions is also underpinned by a record noting a strike at the glass workshop in Tălmaciu, when the Stuckart family failed to pay their workers. The masters and apprentices threatened the owners with a work stoppage and extinguished the fires in the furnaces until they got the food supplies they deserved.[289] But what was considered sufficient amounts of food and drink for the workers? In Diósgyőr, while the assistant castellans reported that they provided ten pints of wine to the masters every day, the number of glassblowers is not recorded so the size of the ration remains uncertain.[290]

The most comprehensive surviving account about these issues is written by a Master Paragini. He describes the food and drink supplies needed for eight masters and three apprentices. In addition to their payment, the masters were also entitled to receive fresh meat three times a day. For lunch, dinner and breakfast they drank red wine with their food. For the evening and the working hours they were given white wine. In one month, they consumed approximately twenty bushels of bread and fifteen barrels of wine.[291]

[287] László Veres, "Üveghuták Magyarországon a 16. Században [Glass Workshops in Hungary in the sixteenth Century]," in *Történeti És Néprajzi Tanulmányok*, ed. Zoltán Ujváry (Debrecen, 1994), 34; H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215; Mészáros, "15. századi üvegműhely Visegrádon," 686; Mester, "Üvegművesség a középjorban és a kora újkorban [Glass Art in the Middle Ages and the Early Modern Age]," 657; Csifféry, *Magyarország üvegipara 1920-ig*, 64, 66, 69–70.

[288] Csifféry, *Magyarország üvegipara 1920-ig*, 73; Csifféry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 138. MOL DL 25709 - https://archives.hungaricana.hu/hu/charters/303082/

[289] Csifféry, *Magyarország üvegipara 1920-ig*, 80.

[290] Csifféry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 138.

[291] Mészáros, "Egy 15. századi toszkán üvegműhely," 228–29.

The masters and their apprentices needed the continuous provisioning of sufficient amounts of food in order to do their job. It was indeed a physically demanding profession, and most of the workers worked extremely long hours in a hot, dangerous environment. Biringuccio's *De la Pirotechnia*, for example, relates the consequences of possible severe burn injuries when a crucible broke during heating or glassblowing. [292] Similarly, Agricola warns the reader in *De re metallica* that the glassblower should remove the blowpipe from his mouth when he takes a breath, otherwise he can "draw the flames into his mouth."[293]

Besides the physical risk, the work was demanding in other respects as well, for example, the intensity of the workload fluctuated from one time to the other, which was probably disruptive for the workers' employment status and lifestyle. Owing to the fact that most of the glass workshops used their furnaces for glassmaking between eight and ten weeks a year, the number of the workers could change as did their working schedules.[294] In those intense weeks, the sleeping schedule of the glassmakers would transform radically. According to Roger Ekirch, medieval people slept in two phases: they went to sleep around sunset and slept roughly until the time of Matins (2-3am), this was called the first sleep.[295] After a short period awake came the second sleep, which lasted till dawn. Both phases were of roughly the same length, but there were some irregularities. If someone was drinking till late, they skipped the first sleep or slept until "*it was fully prime".*[296] *But there were those jobs, where the craftsmen and workers had to do their jobs through the night, for example, metal- and glassworkers who had to attend the furnaces all night long for days in a row.*[297] *They must have had shifts, but at least one of them had to look after the fire in the furnace at all times.* This

[292] Biringuccio, *De La Pirotechnia*, 129.
[293] Agricola, *De Re Metallica*, 1950, 592.
[294] Charleston, "Vessel Glass," 244.
[295] A. Roger Ekrich, *At Day's Close. Night in Times Past.* (New York, London: W.W. Norton & Company, 2006), 390.
[296] Ekrich, 390-91.
[297] Ekrich, 114; Philippe Ariés and Georges Duby, eds., *Revelations of the Medieval World*, A History of Daily Life 2 (Cambridge, Massachusetts, London: Harvard University Press, 1988), 184. Ekrich, *At Day's Close*, 221.

aspect of glass working lay behind an interesting detail from Mugello's aforementioned planned workshop: Master Simone Parigini notes that they need two big beds for the eight masters and the sheets have to be changed every fifteen days.[298]

Conclusion

The aim of this chapter was to investigate the possible origins of the glaziers working in medieval Hungary and examine their working conditions.

The first appearances of Italian glassmakers in the written sources were in the fifteenth century, however, it is more than likely that there were earlier workshops. There are excavated sites, for example at Diósjenő, which date back to the thirteenth century.[299] There is no evidence that the workers there came from Italy. Later in the sixteenth century, the growing number of written sources shows that Polish, German and Hungarian worked side-by-side in medieval Hungary.

The analysis of the social context of glass workshops revealed that monks and women played an important role in glassmaking. The different monastic orders, such as the Cistercians and Paulines established glass workshops in their monasteries, granges to provide themselves with windowpanes and vessels or produce various types of glassware for the adjacent markets. Despite the previous theories that women were not involved in the glassmaking craft, some written evidence exists that they could be owners of the glass workshop, glassblowers, stained-glass makers, and merchants dealing in glass products.

Another social impact of glassmaking was the spread of the names connected to it such as Glaser, Vitripar and Üveges. However, a family name does not always relate to one's

[298] Mészáros, "Egy 15. századi toszkán üvegműhely," 226.
[299] H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő]."

occupation although the spatial distribution of names connected to glassmaking shows that they were more common near to glassworks or woodland areas.

After examining the social questions surrounding the glassmakers, the chapter turns to the issues of the work environment. The written sources describe the needs of the workers including the supply of food and drink. For example, in Diósgyőr, the masters were provided with ten pints of wine every day. [300] Written sources also shed light on what a risky and difficult job glassblowing was for the workers. They had to be cautious because they worked with high temperature objects close to the heated furnaces. The kilns sometimes had to be kept at the same temperature day-and-night for several days during times of more intense production work.

[300] Csiffáry, "A magyarországi üveggyártás 12-16. századi történetének vázlata," 138.

Conclusion

The main goal of this thesis was to examine medieval glass workshops in the Carpathian Basin. It mainly focused, not only on the different furnace and workshop types, but also on the factors involved in their smooth operation and the process of glassmaking itself. In this context, one of the most important research questions concerned the spatial distribution patterns of glass production centers. Regional concentrations of workshops reflect a variety of different factors, both environmental and market related. The natural environment offered resources and materials required for production; thus, it is possible to talk about a particular landscape of glass workshops. Raw materials and secondary raw materials are crucial, but local markets and settlement networks also influenced the basic opportunities possessed by a workshop or the set of technologies it employed as well as the goods it produced.

The first chapter examined and compared the available written and visual sources on medieval glassmaking to find out about the process itself and the basic needs of such workshops generally in the Middle Ages. The results of this chapter suggest that a functioning workshop needed a workspace and a separated house for the workers as well as a storage room for the finished products. The workshop required refractory clay and/or bricks and crucibles that could withstand the high temperatures required of glass production, and a supply of specialized iron tools. Based on the sources, the main factors affecting where a workshop was located included proximity to firewood, water and roads. Furthermore, the process of glassmaking was dependent on an ongoing, predictable supply of raw materials such as silica, alkali flux and lime (Figure 14). However, supplying the vast amounts of firewood needed in glass manufacture must have been the most important economic and environmentally decisive factor in site selection, considering the transportation costs as well. This chapter has also demonstrated that written sources are crucial for dating workshops, but they do not offer

detailed information on the spatial layout of the workshop, or on the actual technology employed at a given workshop site. Pictorial sources can be much more useful in this context, but most of the images date to the Late Middle Ages or Early Modern Period, and they were produced mainly in Italy, Bohemia and, Germany).

The second chapter analyzed the workshops from medieval Hungary, which we have scarce information about. Many of them only appear in documents, such as litigations, legal issues, or named masters: like Bartholomeus Italicus master from Zagreb, who was robbed on his way home back from the market.[301] Some sources even contain information about the types of products the glass workshop made, for instance Hannus and Kwmwl, two masters from Bardejov got paid for their windowpanes. [302] This chapter also discussed the usefulness of some of non-destructive archaeological methods, such as field surveys. Archaeological excavations on a limited scale were also discussed here although results and conclusions drawn about some of these excavations must be handled critically with regards to the quantity and quality of the evidence for glassmaking. For example, it seems that the indications for glassmaking activity at an excavated site at Budapest – 54 Váci Street lacks sufficient indicators for glassmaking activity since only a pit containing burned clay and some stones was found there while glass fragments or crucibles were not found during excavations at the site.[303] Thus, one of the main conclusions of this chapter was that only a strict set of criteria should be used to identify a glass production site.

The third chapter summarizes the known information on the excavated glass workshops at Pásztó, Pomáz, Visegrád and Diósjenő. The main part of the text described their furnaces and explored some parallels to them elsewhere. The chapter followed the same structure and

[301] H. Gyürky, "A magyarországi üvegművesség fellendülése a 15. század közepén [The Rise of the Hungarian Glassworks in the Middle of the fifteenth century]," 215.

[302] Sághelyi, *A magyar üvegesipar története*, 73.

[303] Zádor, "Üveggyártó műhely és lakóépület részlete a középkori Pest területén. [A glass production workshop and a detail of a dwelling in the territory of medieval Pest]," 108–9.

sequence in the description, so that the sites can be compared to each other. The chapter also revisited the question of the traditional typology used for glass workshops in Hungarian archaeology. The glass workshops in the medieval Kingdom of Hungary fell into the general category of the northern type, forest glass-making workshops. However, the strict classifications of the furnace shapes, structures needed to be re-interpreted. This typological analysis did not provide sufficient results in the context of workshop structures. Thus, the basic concept and layout of Hungarian workshops were found to be adapted to their immediate environment and economic opportunities. It seems that each workshop responded in unique ways to the potentials and opportunities presented by the economic, social and environmental context it was located in.

The fourth chapter discussed the installation factors for glass workshops in more detail. The results of this chapter were discussed within the local contexts (landscape), as well as in the large, regional distribution patterns. Analysis of historical maps, the landscape-archaeological approach and interpretation of distribution maps were used to answer the related questions. Vitally important factors for a successful operation were wood and water supplies. Water was not only essential to every part of the glassmaking process but also for the glassmakers to wash and drink. Vast amounts of firewood were needed to heat up the furnaces and keep them at high temperatures, sometimes for days or weeks on end; Beech ash was used in Hungary as a good source of alkali flux, to lower the melting temperature of glass. The most evident needs of glassmaking are the raw materials. Sand or and pebbles provide the basic raw material of glass, but it needed to be cleaned or ground before it could be melted. The need to grind the quarts explains why some workshops were located close to water mills. For example, the glass workshops in Kremnica and Sklené were located close to several water mills listed in a document dating back to 1331.[304] Thus, despite the former hypothesis, it seems that most of

[304] Vadas, "Water Resources in Medieval Hungary," 142–43.

the glassmaking sites were not isolated buildings in the middle of forests or on the edges of towns. These workshops must have been part of a lively road network that enabled them to receive the goods they needed for operating and move the fragile goods they made to market. However, in this context, trading distances must have been less important, if the market for the goods was big enough. The Visegrád and Pomáz sites are clearly connected to this factor, taking into account the markets of Buda, Pest, Visegrád and Esztergom.

Not surprisingly, refractory bricks and crucibles as well as iron tool replacements were continuously required by the glassworks. In the more intense working periods of manufacturing work a weekly or even daily connections were needed. Thus, in Pásztó, the building of the glass workshop was located next to the smithy.[305].

The last chapter presented what is known about the everyday life and the dangers of work in a glass workshop. It also assesses the social status of the glassworkers. As has been clearly demonstrated, it is possible to a certain degree to identify spatial connections between the glass workshops and family names like Glaser and Vitripar. These names surfaced in the written records close to known glass workshops or woodland areas (Figure 61).

To conclude, this thesis has provided a deeper insight into the context of the glass workshops in the Carpathian Basin. Showing that the research into these workshops should not stop at the analysis of the site's spatial layout and the types of glass finds recovered, or the structure of the furnaces. Research into nearby buildings and wells is equally important to understand the glassmaking process. The thesis also sheds light on the significance of the research on the social, environmental, and economic aspects of medieval glass workshops.

This study was limited by the lack of surviving primary written sources and the absence of additional excavations or non-destructive surveys in the surroundings of glass workshops

[305] Valter, "Glass workshop and smithy in Pásztó," 216.

including roads, other types of workshops (pottery, smithy) and the nearest settlements to glassworks.

Considerably more research will need to be done to have a clearer image of the economic, environmental and social impact of medieval glassmaking and glass workshops in the Carpathian Basin in the form of excavations and field surveys, not only on the workshops but also on the settlements, iron tools, pottery, fire resistant clay sources and road networks. On a large scale, archaeometric studies can also change the basic research situation in this field. Taking into account the results of this present work, it would be equally important to determine the connections and the origins of the raw materials used to make the glass itself at individual workshops. With this complex approach, it is possible to draw a less fragmented image of this important craft despite the thousands of pieces of fragmented glass and the limited number of relevant texts.

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Appendices

Figures and maps

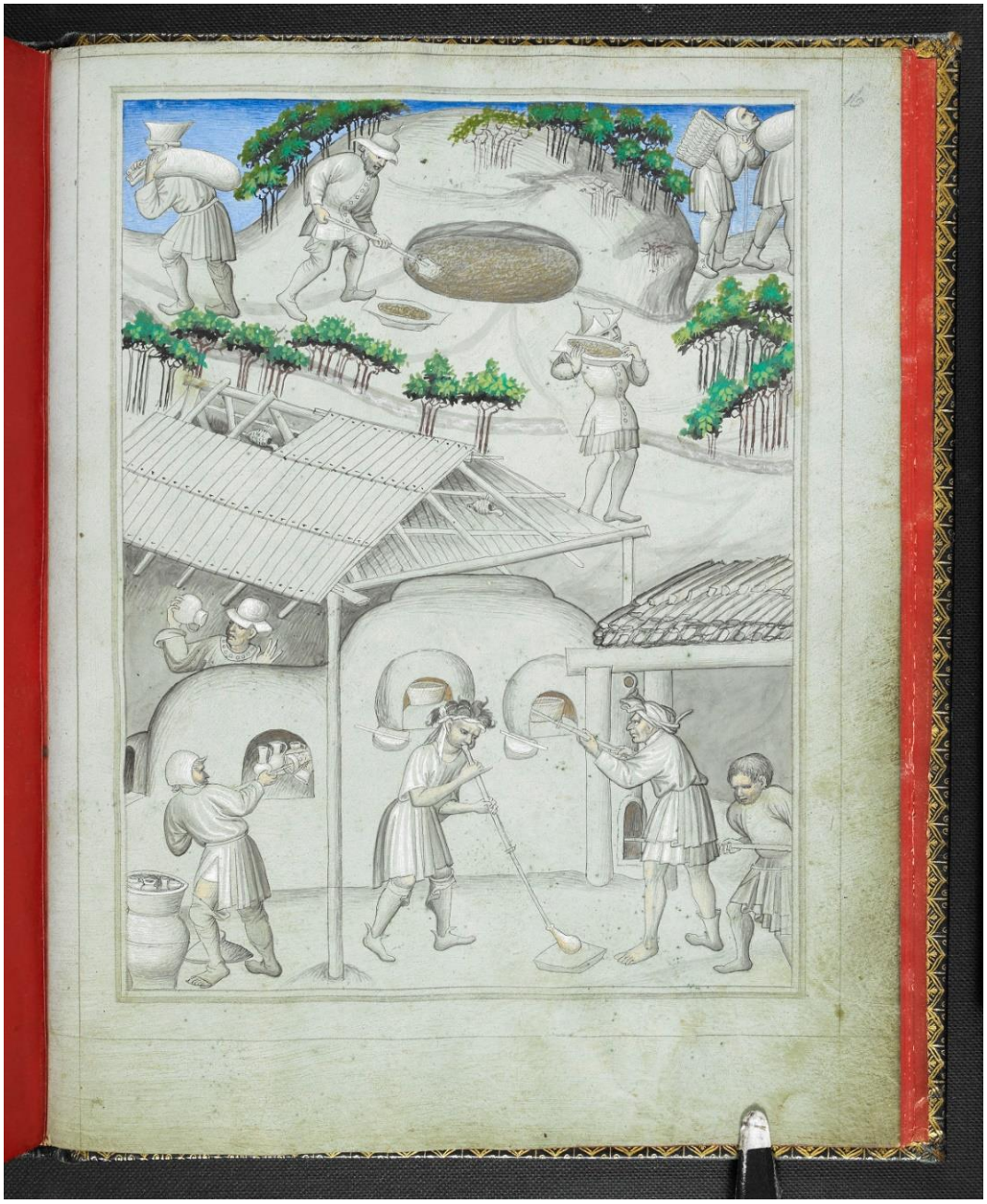


Figure 1 Miniature from a MS of 'Sir John Mandeville's Travels' Probably Bohemian; c. 1420. (Source: B.L. MS Add 244189 f. 16) http://www.bl.uk/catalogues/illuminatedmanuscripts/ILLUMIN.ASP?Size=mid&IllID=57700)

Figure 2. Depiction of a glass furnace from 1440 (Source: "Tractatus de Herbis" (illustrated treatise, Italy, N. (Lombardy), c 1440), fol. 101 v., Sloane 4016, Brithis Library)

Figure 3 Depiction of an annealing furnace from 1458 (Source: Tractatus de herbis, Modena, Biblioteca Estense Universitaria, Est 28 e M 59, fol. 138r) http://d2aohiyo3d3idm.cloudfront.net /publications/virtuallibrary/089236758X.pdf)

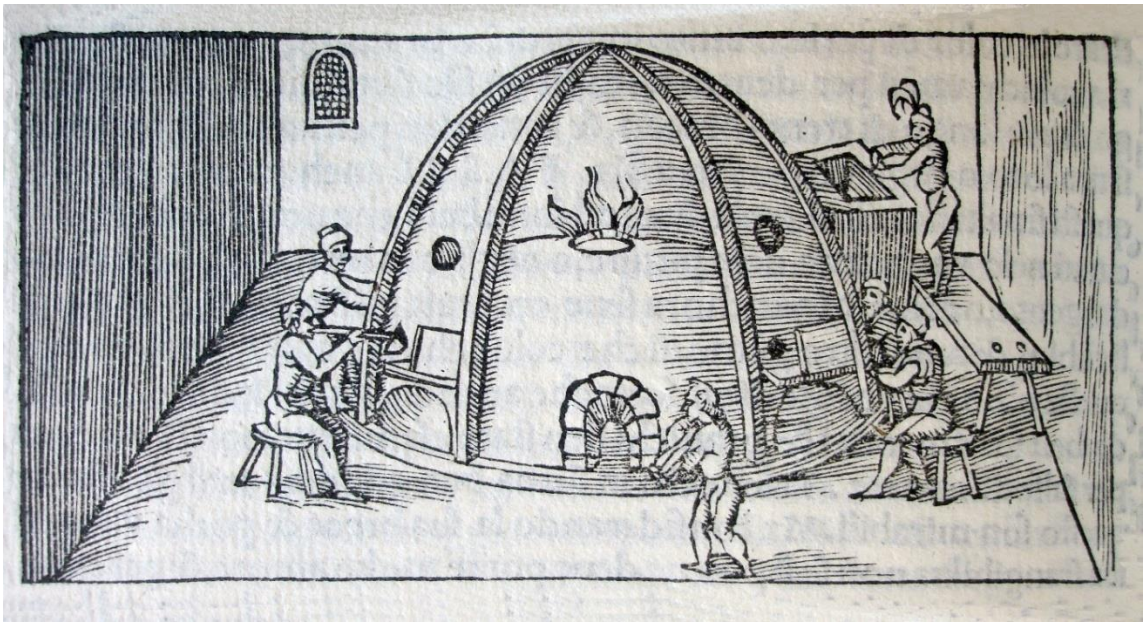
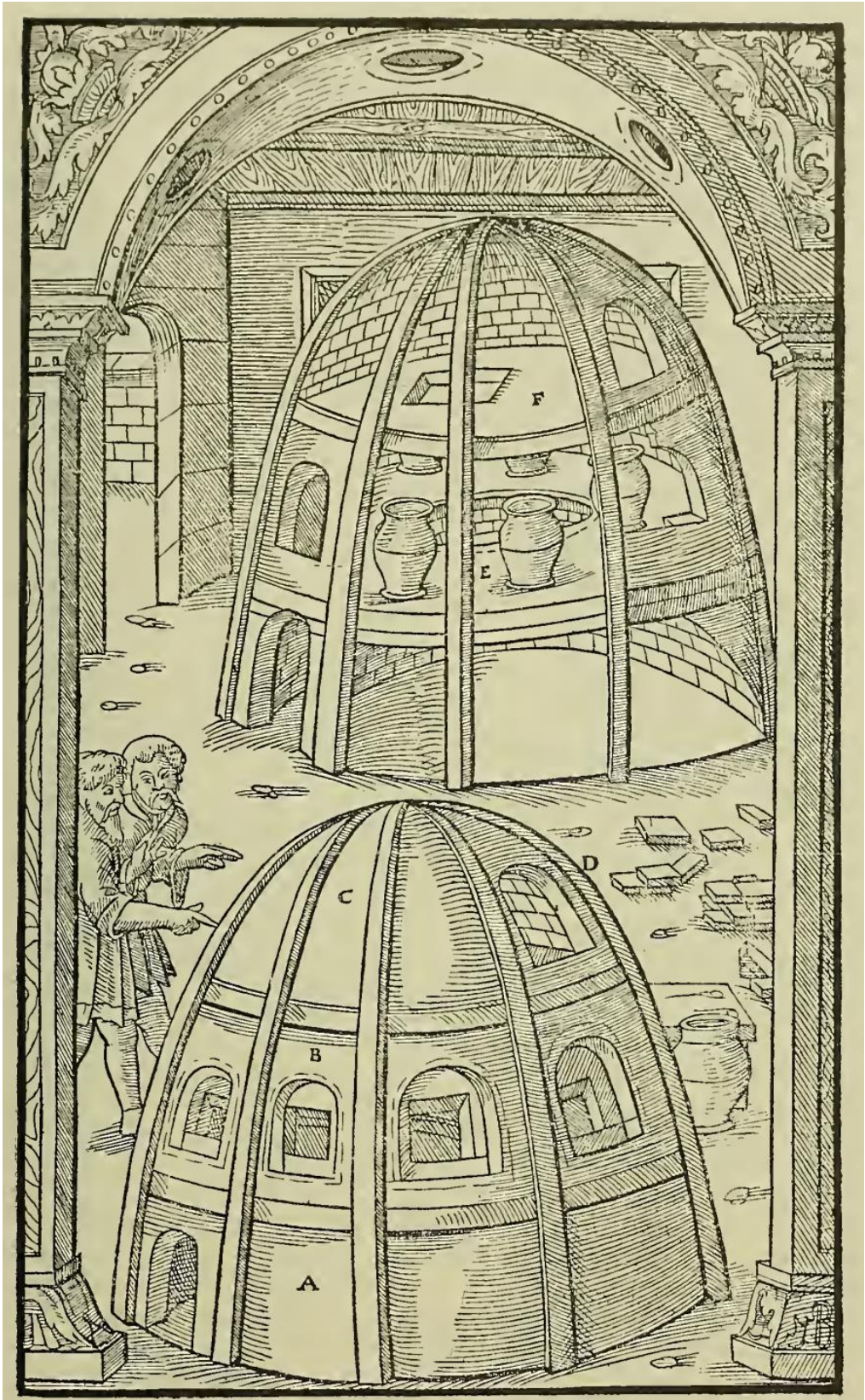


Figure 4 The depiction of a glass furnace from Biringuccio's De la pirotechnia (Source: Vannoccio Biringuccio, The Pirotechnia of Vannoccio Biringuccio. The Classic Sixteenth-Century Treatrise on Metal and Metallurgy, *trans. Cyril Stanley Smith and Martha Teach Gnudi (New York: Dover Publications, 1990), 133.)*

Figure 5 Depiction of a melting furnace from De re metallica (Source: Georgius Agricola, De Re Metallica, *trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 587.)*

Figure 6 The picture of a glass- and an annealing furnace from the De re metallica (Source: Georgius Agricola, De Re Metallica, *trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 588.)*

Figure 7 Glassblowing scene with a glass kiln. (Source: Georgius Agricola, De Re Metallica, *trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 591).*



A—Lower chamber of the other second furnace. B—Middle one. C—Upper one.
D—Its opening. E—Round opening. F—Rectangular opening.

Figure 8 The depiction of a glass- and an annealing furnace built together (Source: Georgius Agricola, De Re Metallica, *trans. Herbert Clark Hoover and Lou Henry Hoover (New York: Dover Publications, 1950), 589).)*

Figure 9 Francesco I (left) visiting his glassworks. Giovanni Maria Butteri's painting (1570–1572). (Source: Francesco visiting glassworks, 1570-1572, by Giovanni Maria Butteri (1540-1606), oil on board, 147x86 cm. Studiolo of Francesco I, Palazzo Vecchio, Florence. Italy, 16th century. (Photo by DeAgostini/Getty Images))

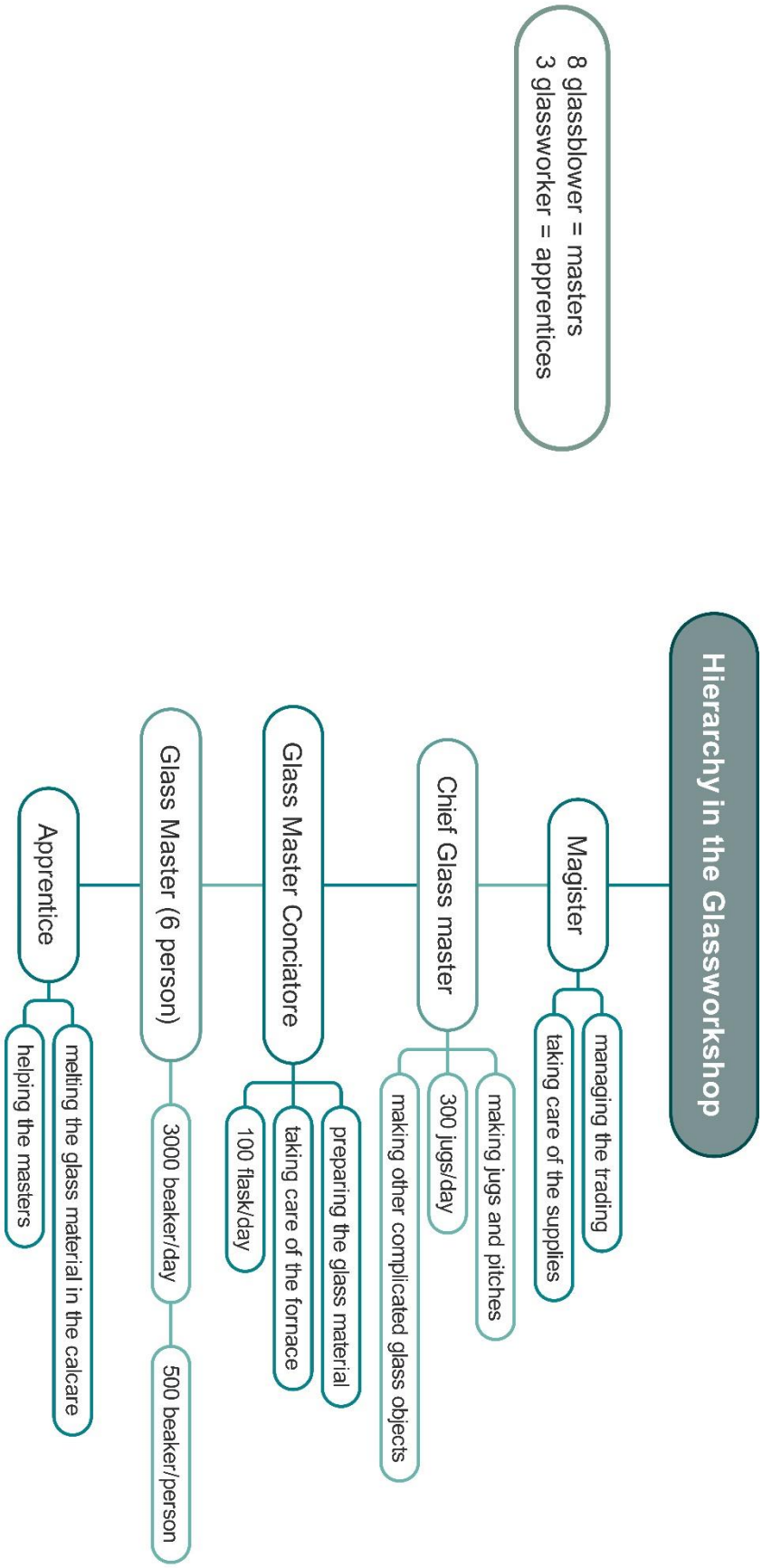


Figure 10 The social hierarchy in a glass workshop (based on Parigini's description, created by Mónika Gácsi)

Crucibles	**Vannoccio Biringuccio**	**Georgius Agricola**		***Cooling Receptacles***	**Georgius Agricola**
Mouth diameter	0,5 braccio = 35 cm	1 foot = 30 cm		Length	3 feet = 91 cm
Belly diameter	No data	1,5 feet = 45 cm		Height	1,5 feet = 45cm
Bottom diameter	0,5 braccio = 35 cm	1 foot = 30 cm		Width	1 foot = 30 cm
Height	0.75 braccio= 52,5 cm	2 feet = 61 cm			

Table 1 The measurements of glass melting pots based on the written sources

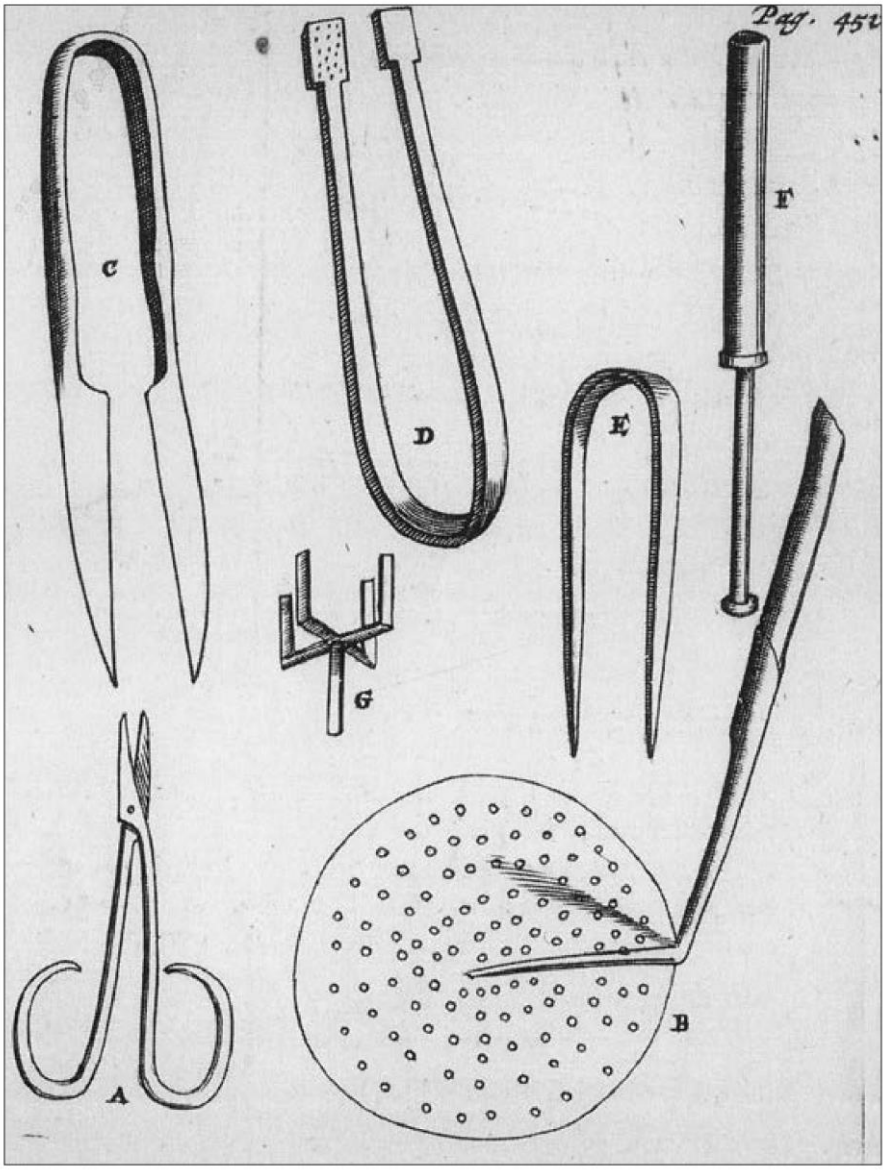


Figure 11 Depiction of iron tools (Source: Orsolya Mészáros, "A középkori üvegkészítés fémeszközei [The Metal Tools of the Medieval Glassmaking]," in Hadi és más nevezetes történetek. Tanulmányok Veszprémy László tiszteletére*, ed. Katalin Mária Kincses (Budapest: HM Hadtörténeti Intézet és Múzeum, 2018), 355.)*

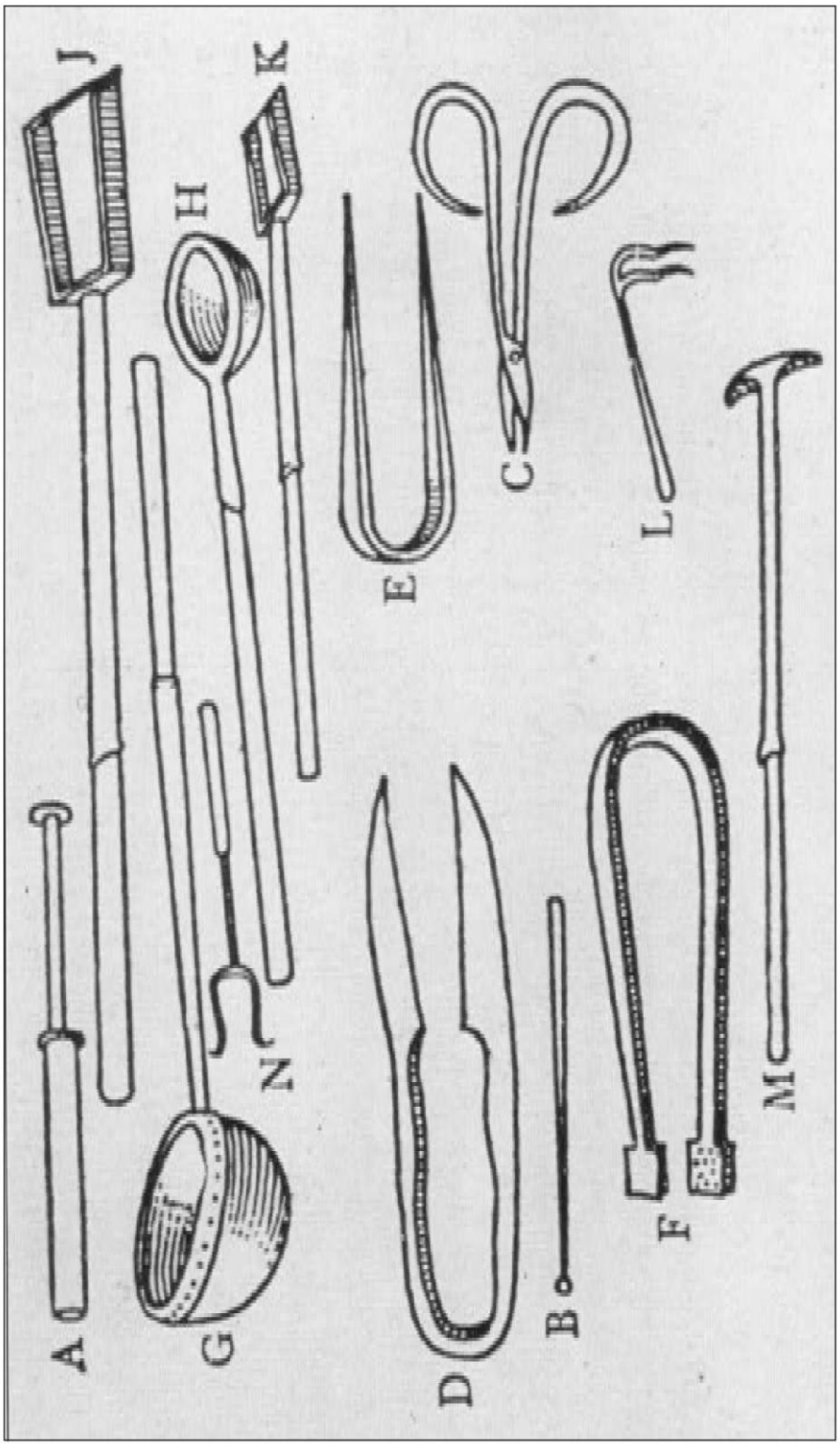


Figure 12 Depiction of iron tools (Source: Orsolya Mészáros, "A középkori üvegkészítés fémeszközei [The Metal Tools of the Medieval Glassmaking]," in Hadi és más nevezetes történetek. Tanulmányok Veszprémy László tiszteletére*, ed. Katalin Mária Kincses (Budapest: HM Hadtörténeti Intézet és Múzeum, 2018), 356.)*

		Vannoccio Biringuccio	Georgius Agricola	
Melting furnace	length	3 braccio = 2 m 10 cm	6 feet = 1m 82 cm	
	width	2 braccio = 1 m 40 cm	4 feet = 1 m 21 cm	
	height	1 braccio = 0 m 70 cm (without the firebox)	2 feet = 0 m 61 cm (without the firebox / hearth)	
Glass furnace	diameter	4 braccio = 2 m 80 cm	10 feet = 3 m 4 cm	8 feet = 2 m 43 cm
	height	6 braccio = 4 m 20 cm (1 braccio = 70 cm for the hearth, 3 braccio = 2m 10 cm for the upper chamber, 2 =1 m 40 cm braccio for the top chamber)	8 feet = 2 m 43 cm (with 2 chambers)	12 feet = 3 m 65 cm (with 3 chambers)
Annealing furnace	length	no separate annealing furnace	8 feet = 2 m 43 cm	no separate annealing furnace
	width		6 feet = 1m 82 cm	
	height		2 chambers, the upper one is more than 2 feet = 0 m 61 cm (because the earthenware receptacles are 2 feet high)	

		Theophilus Presbyter	
Melting furnace	length	5 feet = 1 m 52 cm	
	width	10 feet = 3 m 4 cm	
	height	4 feet = 1m 21 cm	Melting and Glass furnace (1/2) = 15 feet length + 10 feet width
Glass furnace	length	10 feet = 3 m 4 cm	
	width	10 feet = 3 m 4 cm	
	height	8 feet = 2 m 43 cm	
Annealing furnace	length	10 feet = 3 m 4 cm	
	width	8 feet = 2 m 43 cm	
	height	4 feet = 1m 21 cm	
Kiln for spreading out	length	6 feet = 1 m 82 cm	
	width	4 feet = 1m 21 cm	
	height	3 feet = 0 m 91 cm	
Kiln for painted glass	length	2 feet = 0 m 61 cm	
	width	1, 5 feet = 0 m 45 cm	
	height	1, 5 feet = 0 m 45 cm	

Table 2 The comparison of the size of different type of furnaces as specified in surviving written sources

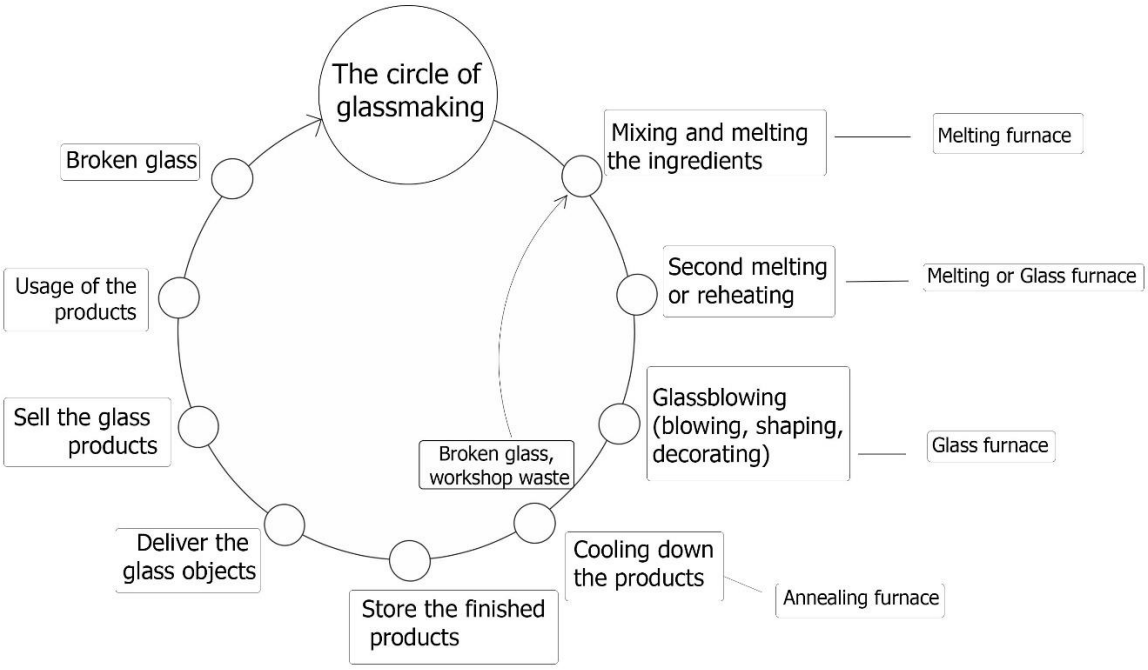


Figure 13 The process of glassmaking (created by Mónika Gácsi)

Figure 14 The needs of a glass workshop based on the written sources (created by Mónika Gácsi)

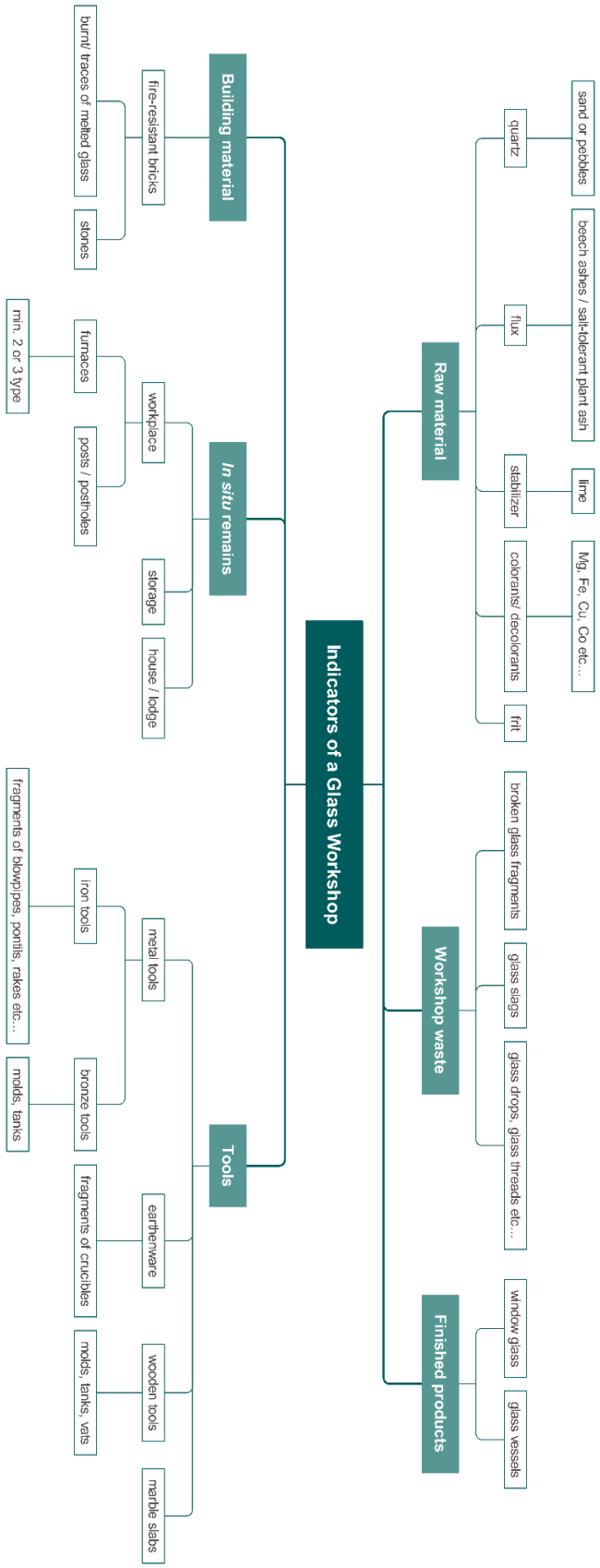


Figure 15 Different indicators marking the presence of a glass workshop on an archeological site (created by Mónika Gácsi)

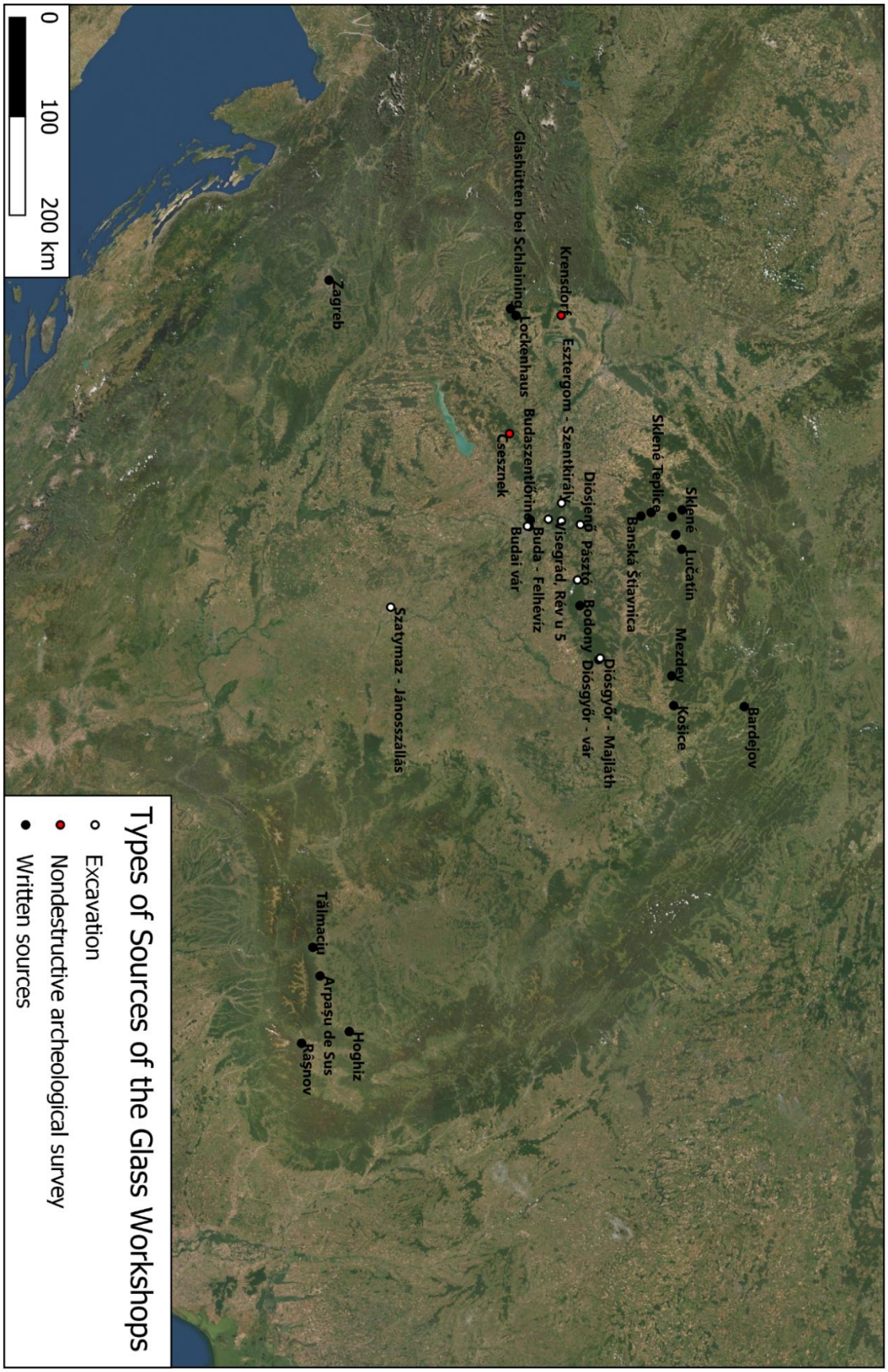


Figure 16 Different type of sources about the glass workshops in the Carpathian Basin (created in QGIS by Mónika Gácsi)

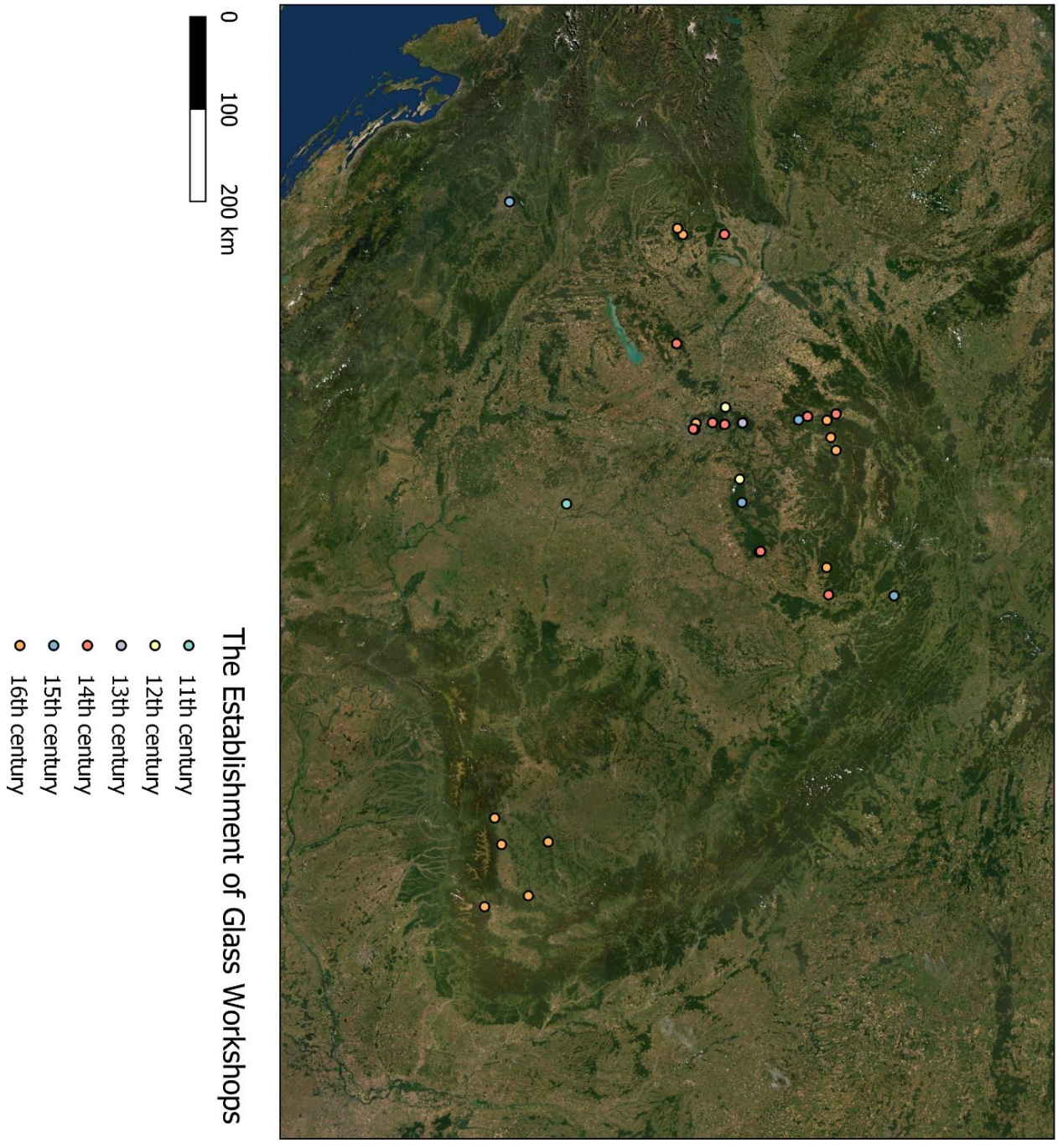


Figure 17 Glass workshops by their establishment dates (created in QGIS by Mónika Gácsi)

2. kép: A műhely részlete a tűzhellyel és a cölöplyukakkal, észak felől
Fig. 2: Detail of the workshop with the furnace and the postholes from the north

Figure 18 Photo of the remains of a glass workshop (Budapest, 54 Váci Street) (Source: Judit Zádor, "Üveggyártó műhely és lakóépület részlete a középkori Pest területén. [A glass production workshop and a detail of a dwelling in the territory of medieval Pest]," Aquincumi füzetek *19 (2013): 109.)*

3. kép: A műhely átégett köves felszíne délről nézve
Fig. 3: The heavily burned stony level of the workshop from the south

Figure 19 The burned surface of the workshop (Budapest, 54 Váci Street) (Source: Zádor, 109.)

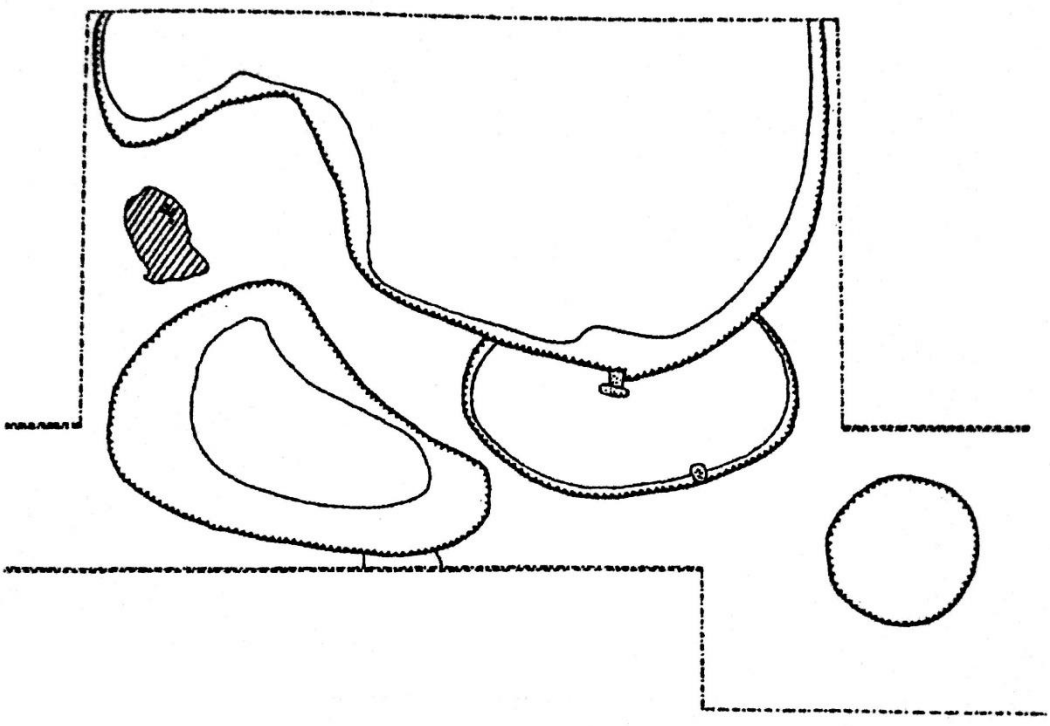


Figure 20 The pit-system at Visegrád, 34 Fő Street (Source: Edit Mester, Középkori üvegek [Medieval Glasses], *Visegrád Régészeti Monográfiái 2 (Visegrád: MNM Mátyás király Múzeuma, 1997), 127.)*

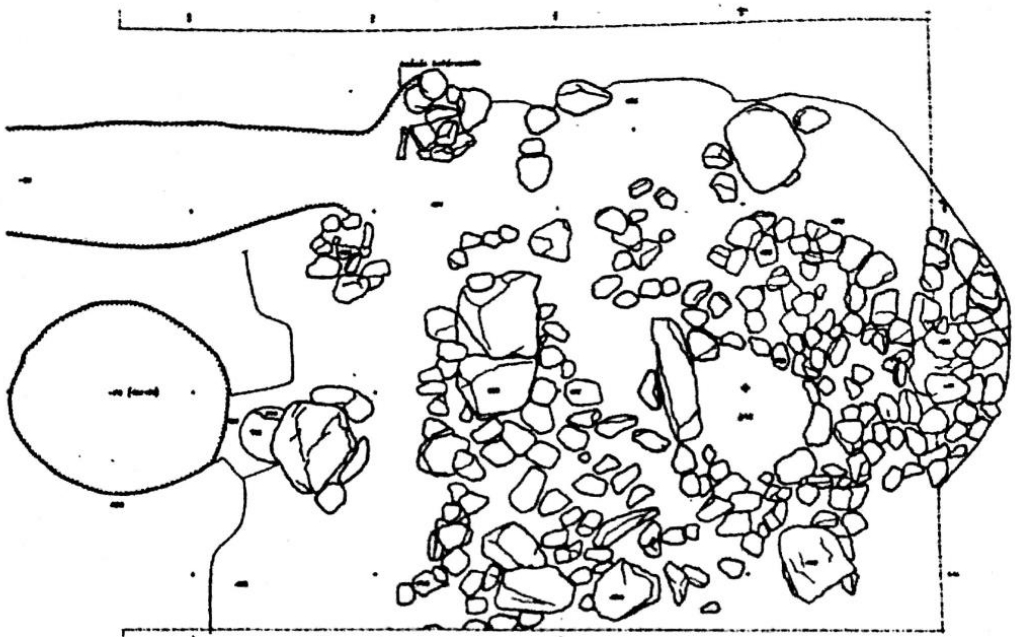


Figure 21 The groundplan of the furnaces at Visegrád, 34 Fő Street (Source: Mester, 128.)

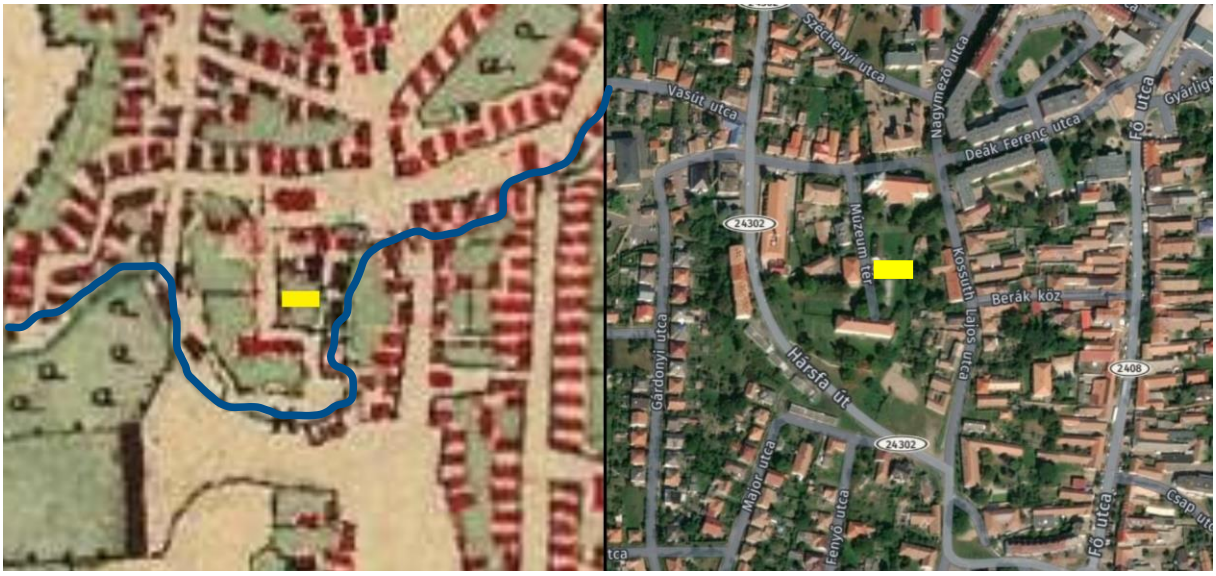


Figure 22 The glass workshop in Pásztó on the 2nd military survey and on the current Google Earth map

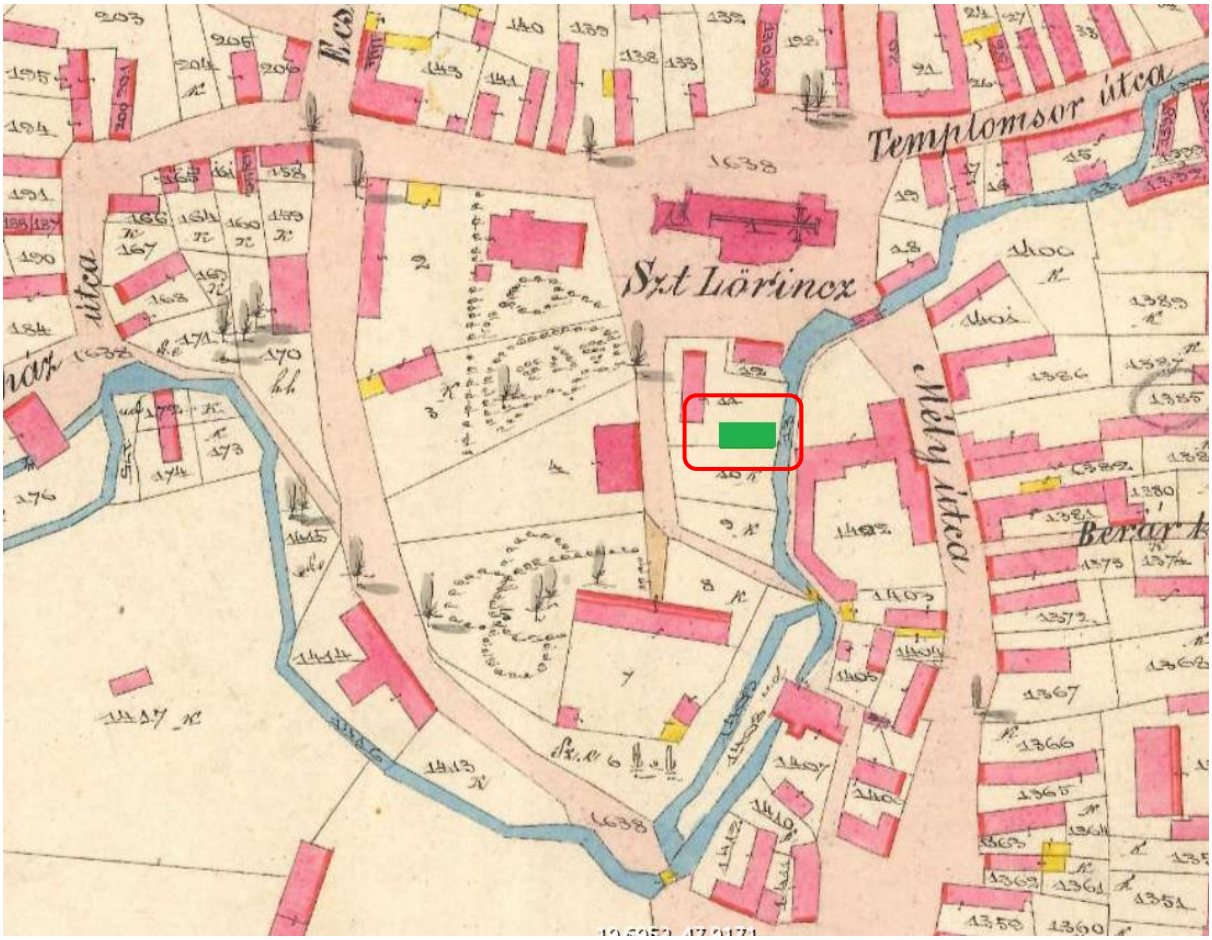


Figure 23 The glass workshop of Pásztó on a nineteenth century cadastral map

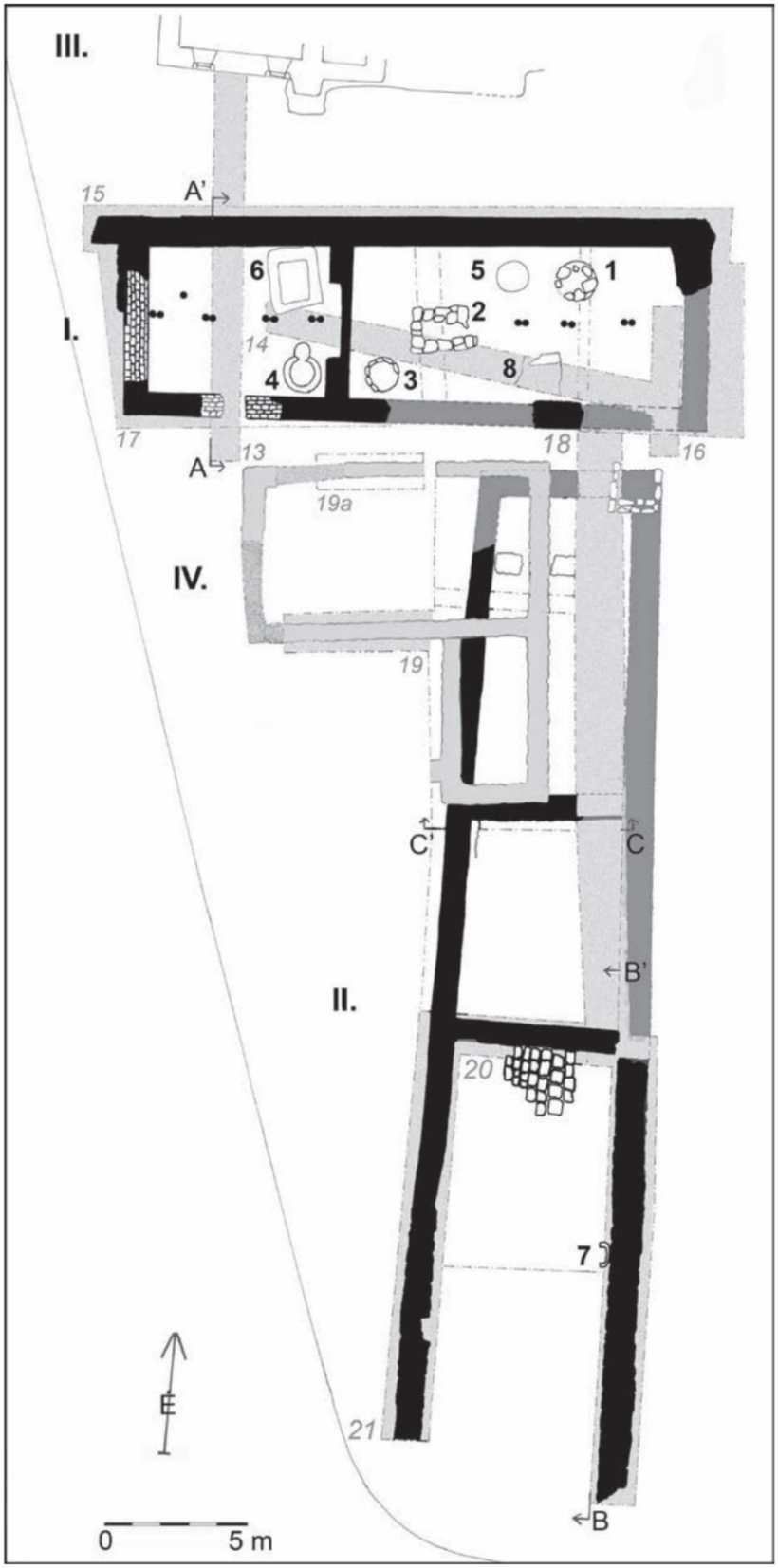


Figure 24 The layout of the glass workshop and the smithy in Pásztó (I. glass workshop; II. smithy) (Source: Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban [An Arpadian period (11th-13th century) glass workshop and smithy in the monastery of Pásztó]," Archaeologiai Értesítő *140 (2015): 197.)*

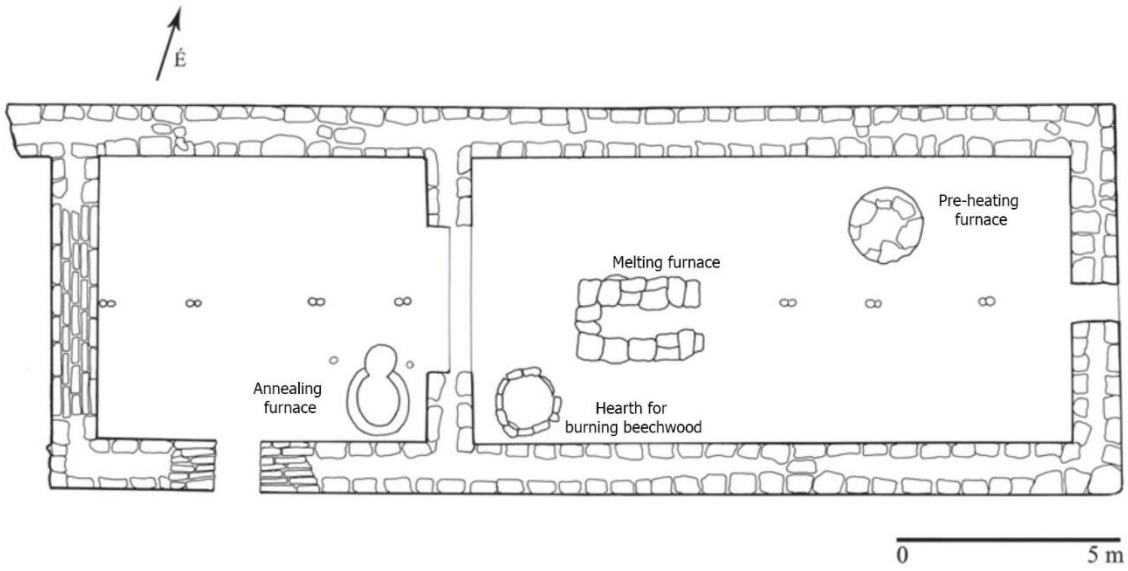


Figure 25 The ground plan of the glass workshop in Pásztó (Source: Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban [An Arpadian period (11th-13th century) glass workshop and smithy in the monastery of Pásztó]," Archaeologiai Értesítő *140 (2015): 214.)*

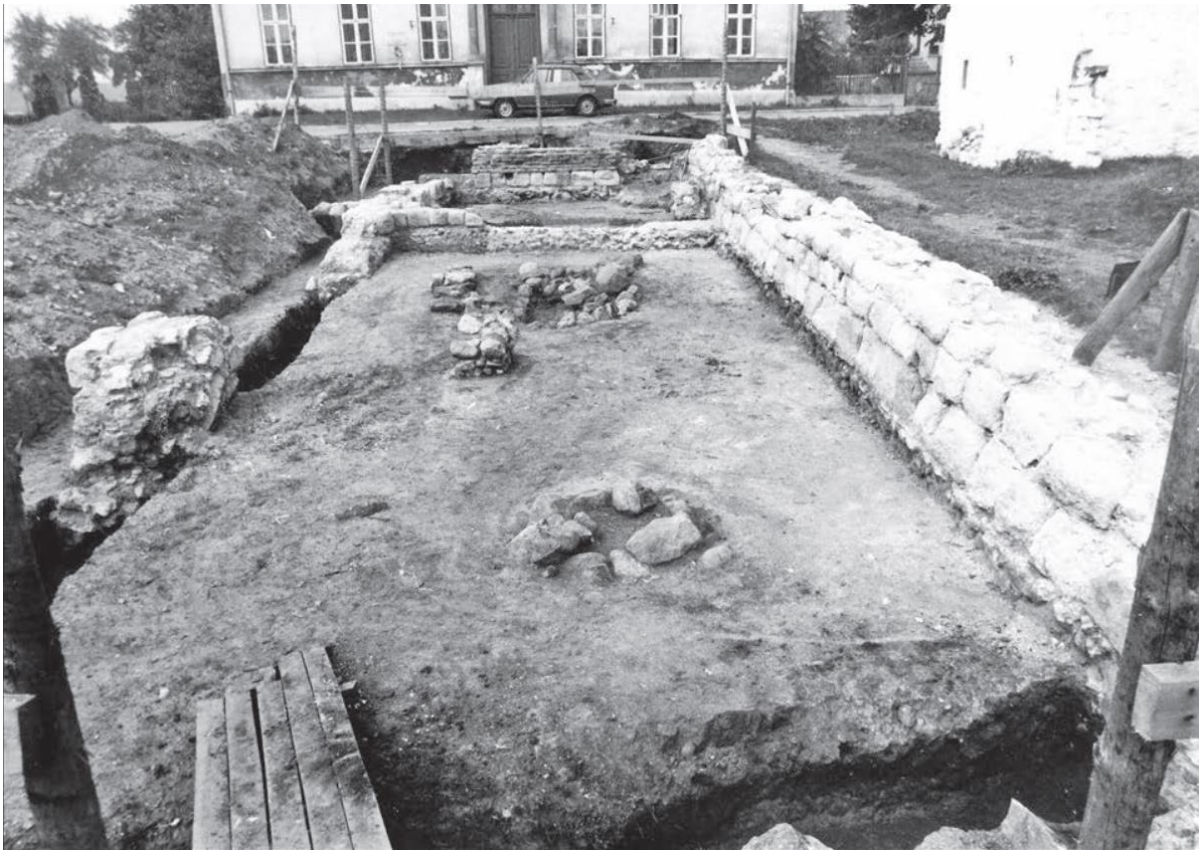


Figure 26 Photo of the glass workshop of Pásztó from the east side (The photo was taken by Ilona Valter) ((Source: Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban [An Arpadian period (11th-13th century) glass workshop and smithy in the monastery of Pásztó]," Archaeologiai Értesítő *140 (2015): 213.)*

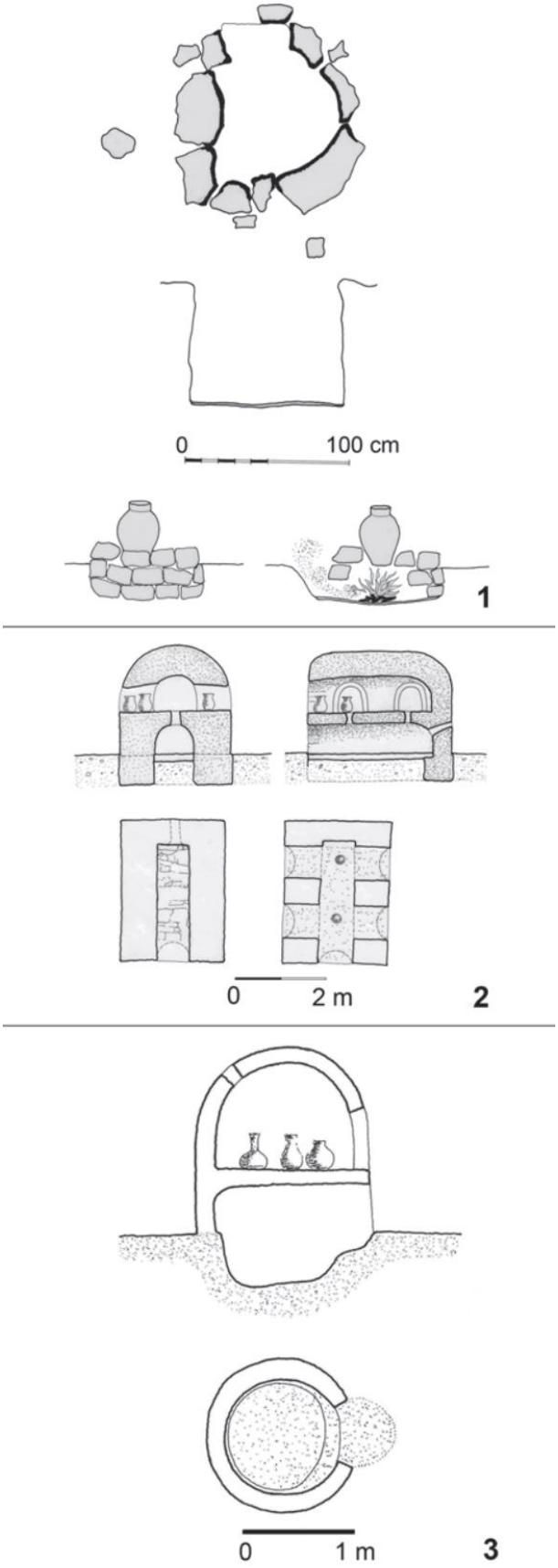


Figure 27 Reconstructions of the furnaces based on Theophilus Presbyter's description (Source: Ilona Valter, "Árpád-kori (11-13. század) üveghuta és kovácsműhely a pásztói monostorban [An Arpadian period (11th-13th century) glass workshop and smithy in the monastery of Pásztó]," Archaeologiai Értesítő *140 (2015): 215.)*

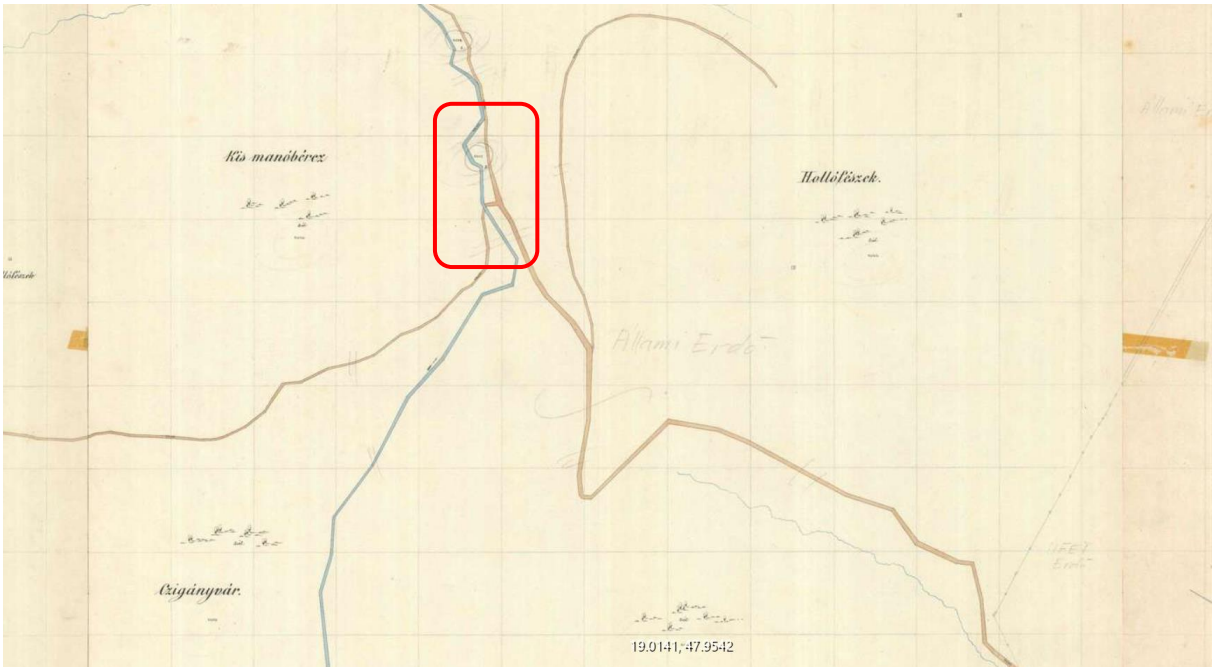


Figure 28 Location of the glass workshops near to Diósjenő on a nineteenth-century cadastral map

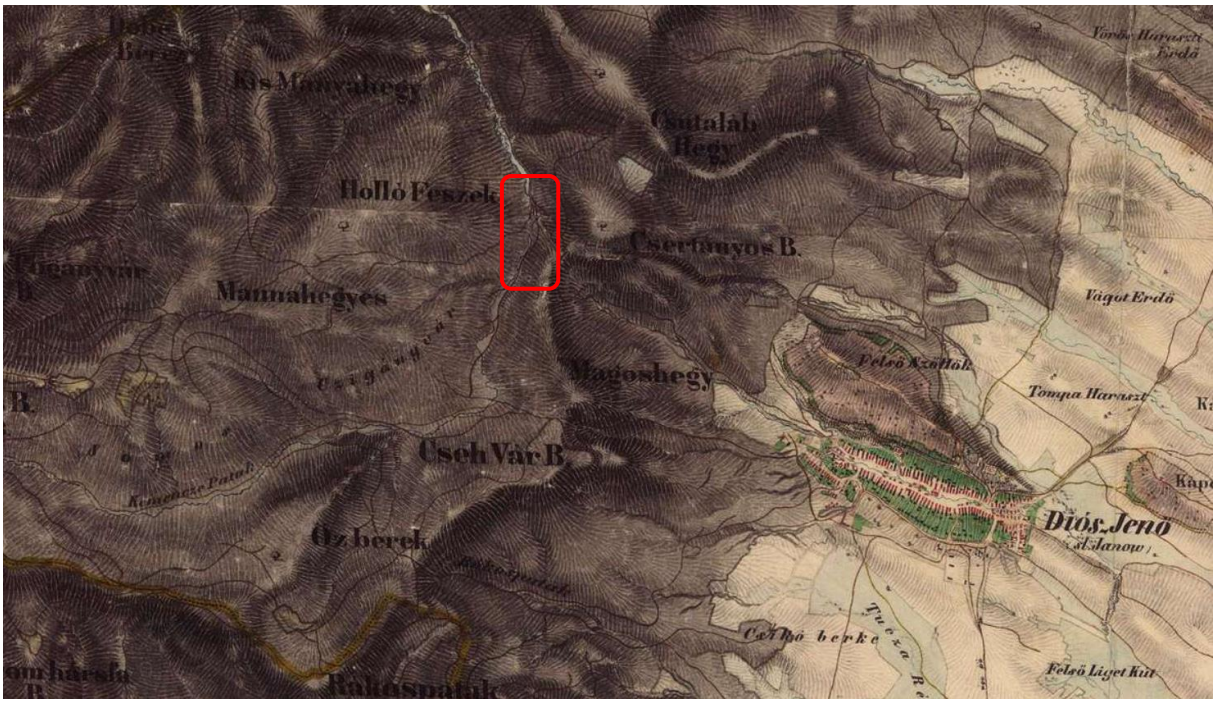


Figure 29 The glass workshops near to Diósjenő on the Second Military Survey

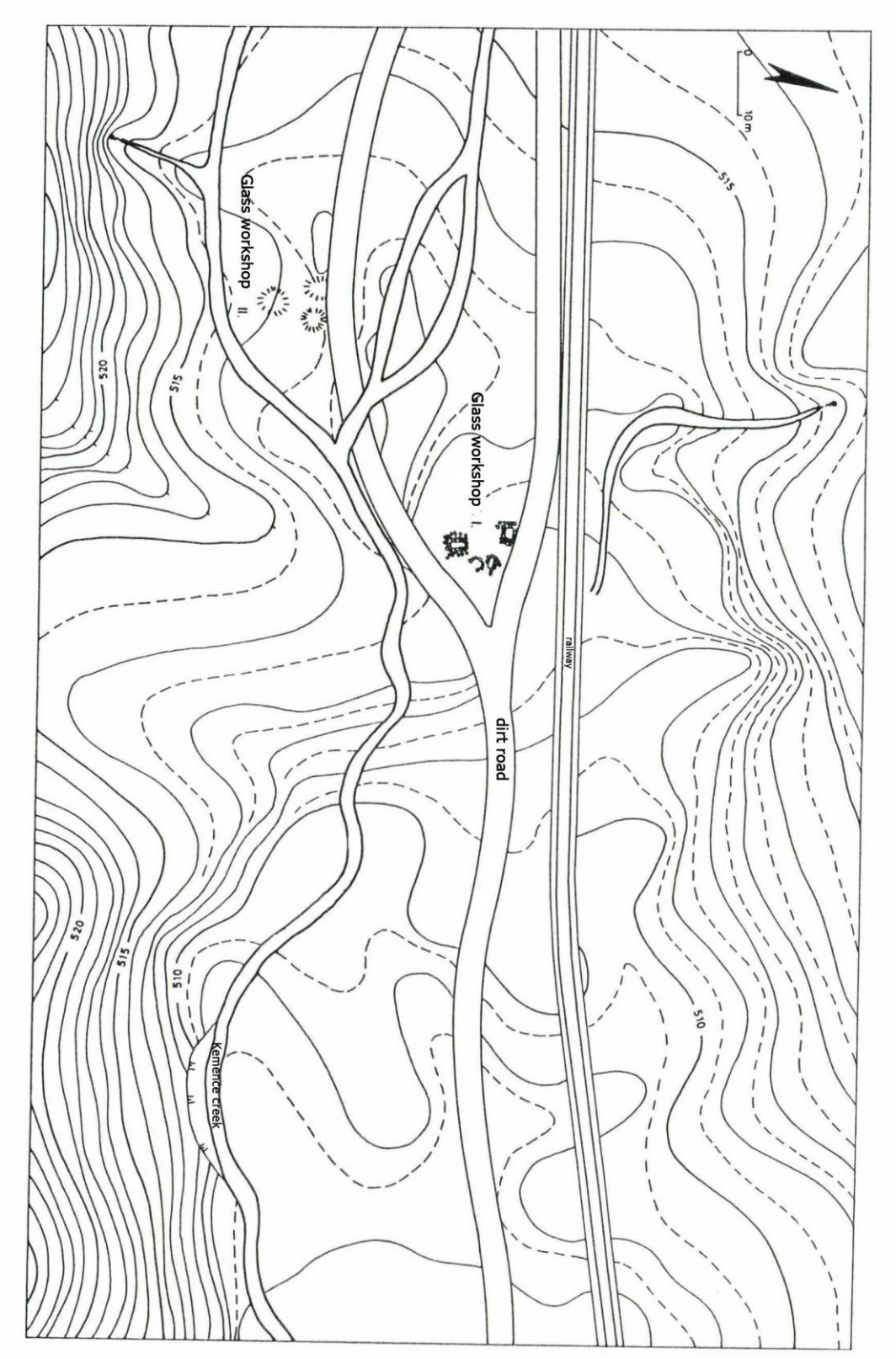


*Figure 30 The first and second glass workshop near to Diósjenő (translated by Mónika Gácsi) (*Edit Mester, Középkori üvegek [Medieval glasses]*, Visegrád régészeti monográfiái 2 (Visegrád: Visegrádi Mátyás Király Múzeum, 1997), 105.)*

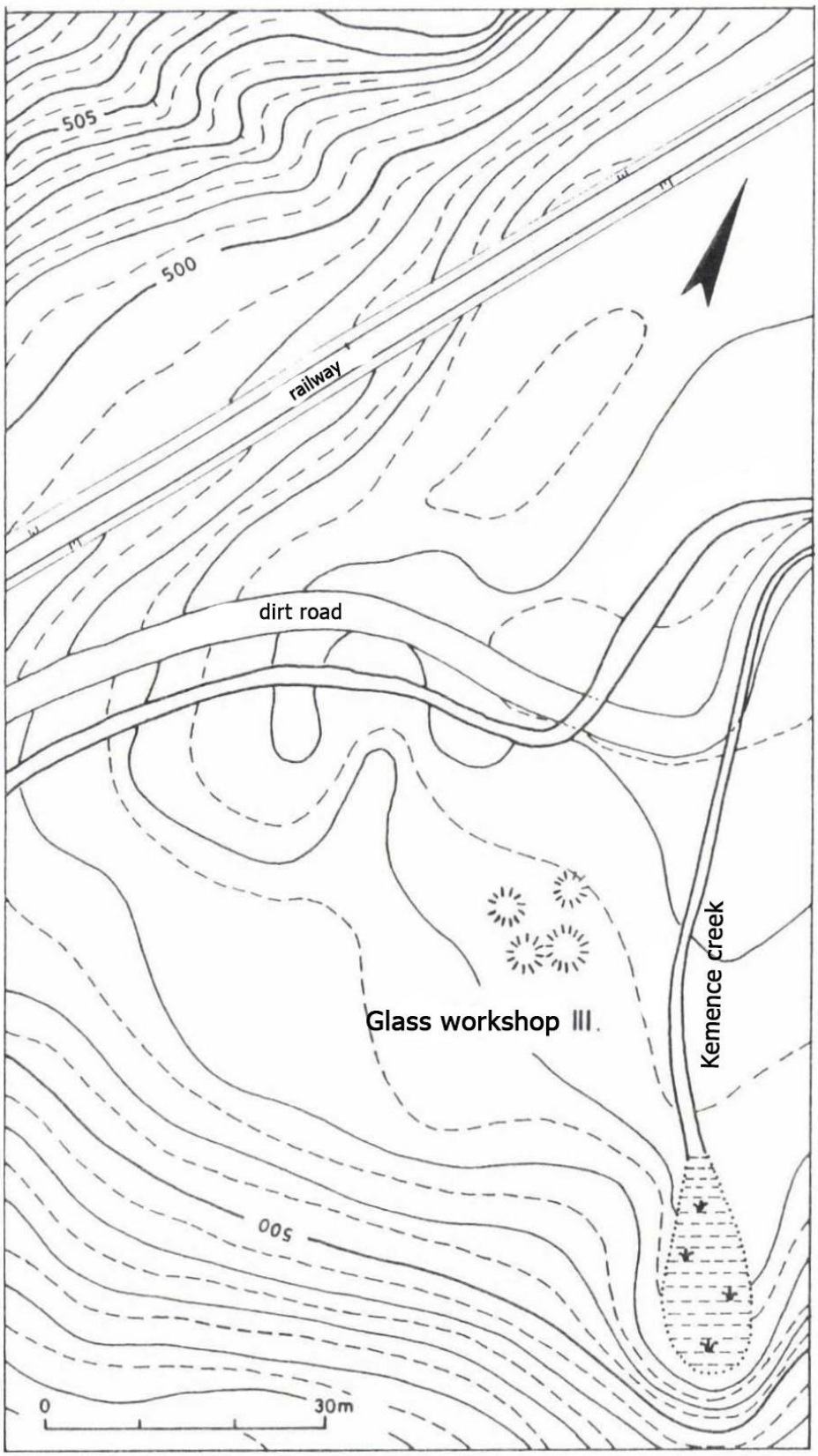


Figure 31 The location of the third glass workshop near to Diósjenő (translated by Mónika Gácsi) (Source: *Katalin H. Gyürky, "Középkori üveghuta feltárása a Nógrád megyei Diósjenő közelében [The Excavation of the Medieval Glassworkshop in Nógrád County, near to Diósjenő],"* Archaeológiai Értesítő *119 (1992): 122.)*

Figure 32 The ground plan of the kilns at the 1st glass workshop at Diósjenő (translated by Mónika Gácsi) (Source: Mester, Középkori üvegek [Medieval glasses]*, 104.)*

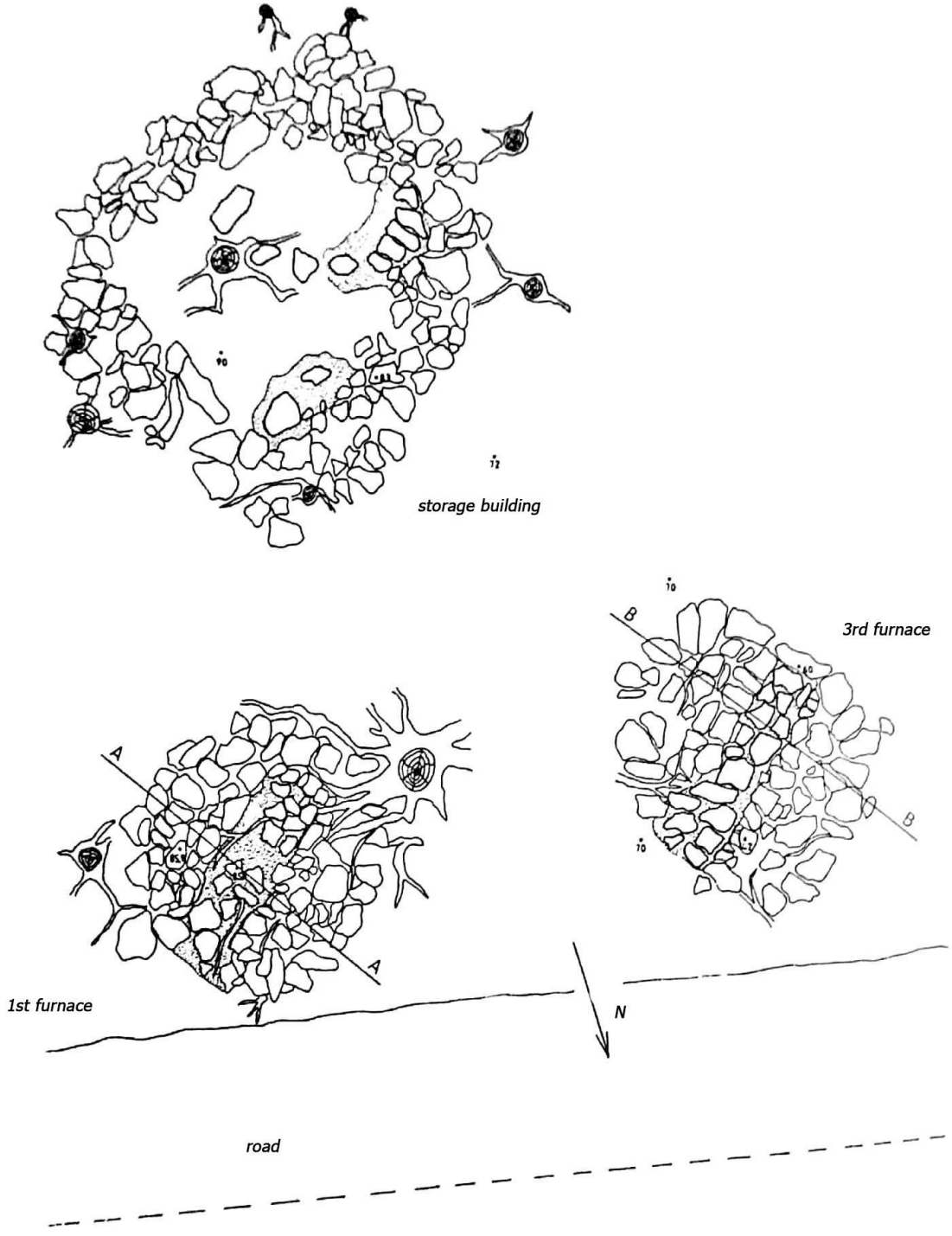


Figure 33 The ground plan of the second glass workshop at Diósjenő (translated by Mónika Gácsi) (Source: Mester, 104.)

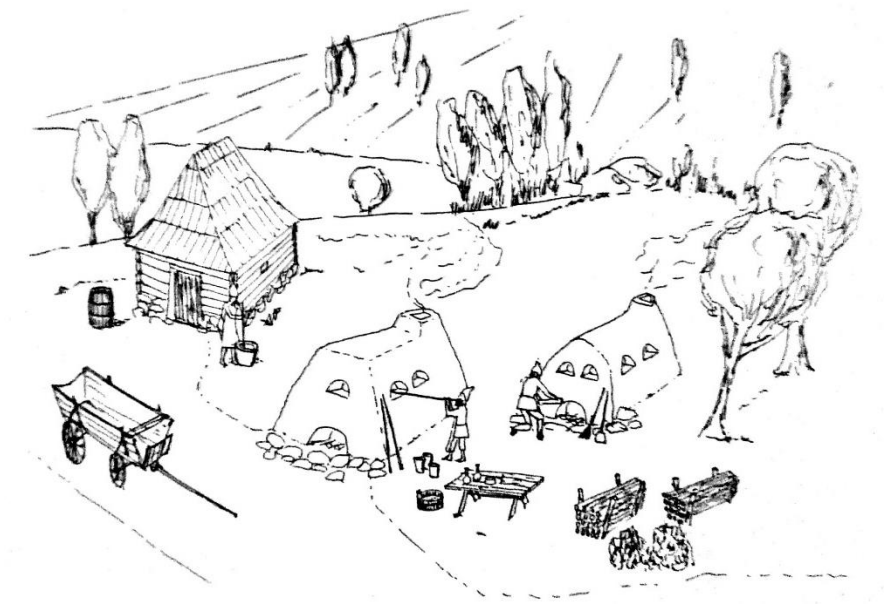


Figure 34 Reconstruction drawing of the second glass workshop at Diósjenő (Source: Edit Mester, Középkori üvegek [Medieval glasses]*, Visegrád régészeti monográfiái 2 (Visegrád: Visegrádi Mátyás Király Múzeum, 1997), 126).*

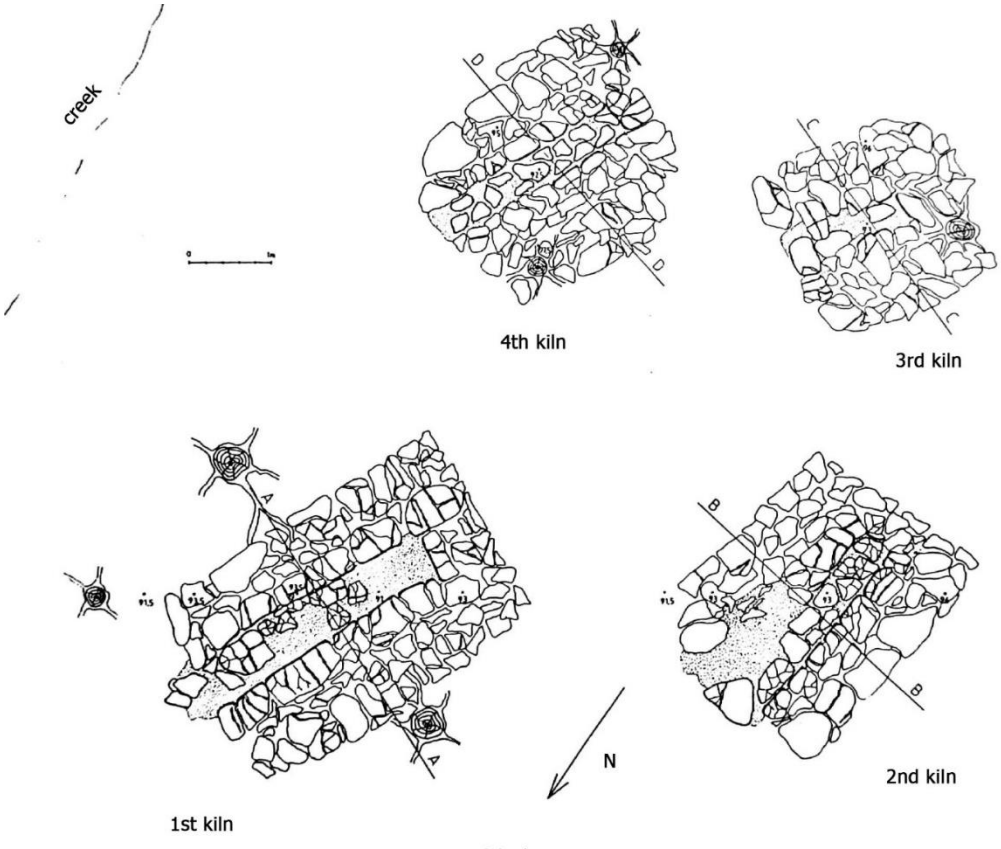


Figure 35 The ground plan of the third glass workshop near to Diósjenő (translated by Mónika Gácsi) (Source: Edit Mester, Középkori üvegek [Medieval glasses]*, Visegrád régészeti monográfiái 2 (Visegrád: Visegrádi Mátyás Király Múzeum, 1997), 115).*

Glass Workshops	Obj.	Furnace	Measurements	Orientation
I.	1	annealing or pre-heating	190 x 130 cm	Northwest-Southeast
	2	annealing or pre-heating	240 x 170 cm	Northeast – Southwest
	3	melting	380 x 220 cm	North-South
II.	1	melting	250 x 300 cm	Northeast – Southwest
	3	annealing or pre-heating	290 x 260 cm	Northeast – Southwest
III.	1	melting	265 x 400 cm	Northeast – Southwest
	2	annealing or pre-heating	360 x 340 cm	Northeast – Southwest
	3	annealing or pre-heating	230 x 240 cm	Northeast – Southwest
	4	annealing or pre-heating	260 x 300 cm	Northeast – Southwest
Glass Workshops	**Obj.**	**Storage buildings**	**Measurements**	
I.	4		470 x 400 cm	
II.	2		335 x 435 cm	

Table 3 The measurements of the furnaces and storage buildings from Diósjenő

Figure 36 The location of the glass workshop of Pomáz - Nagykovácsi on the First Military Survey

Figure 37 The location of the glass workshop of Pomáz - Nagykovácsi on a nineteenth-century cadastral map. The caption "Puszta templom" indicates the church's ruins and the glass workshop's place on the map.

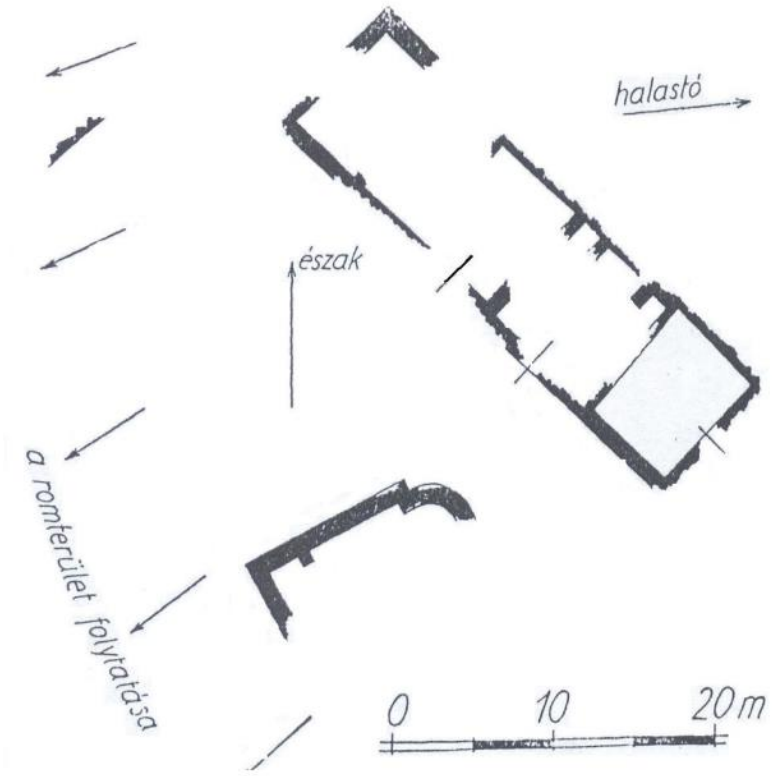


Figure 38 László Krompecher's groundplan of the site (Source: László Krompecher, "A Pilisi Apátság Romjainak Fellelése [Finding the Ruins of the Abbey at Pilis]," Technika. A Magyar Mérnökök Lapja 1–10, no. 15 (1935 1934): 36–37.)

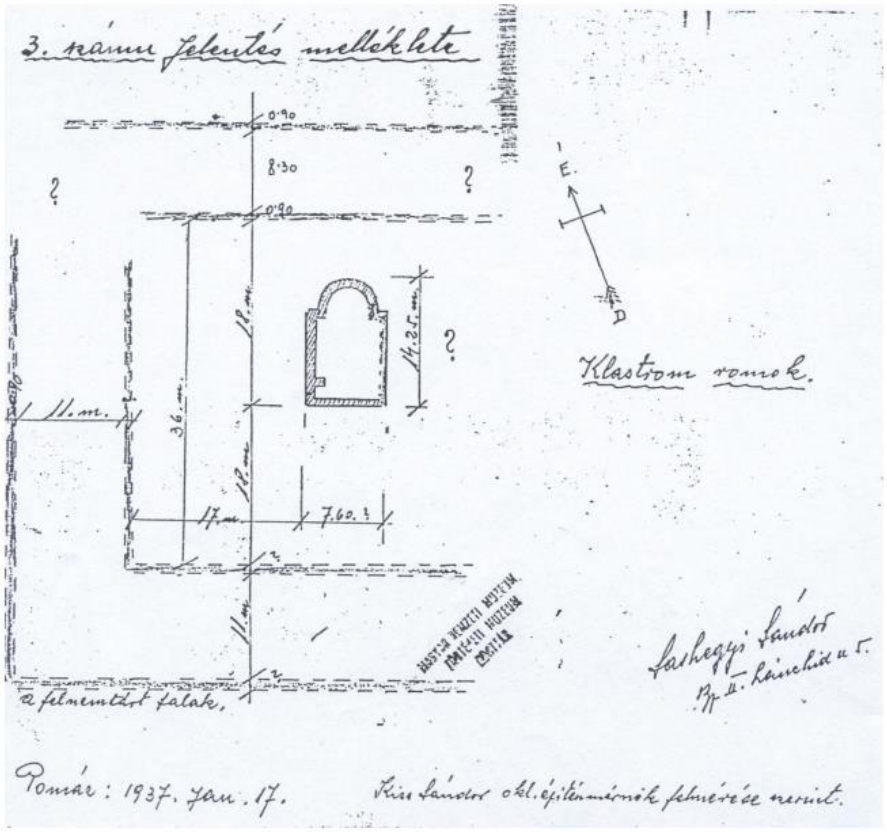


Figure 39 The ground plan of the church and its surrounding buildings by Sándor Sashegyi (Source: József Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains. The Long and Complex History of an Árpád Period Village Church," Hungarian Archeology *Winter (2014): 2.)*

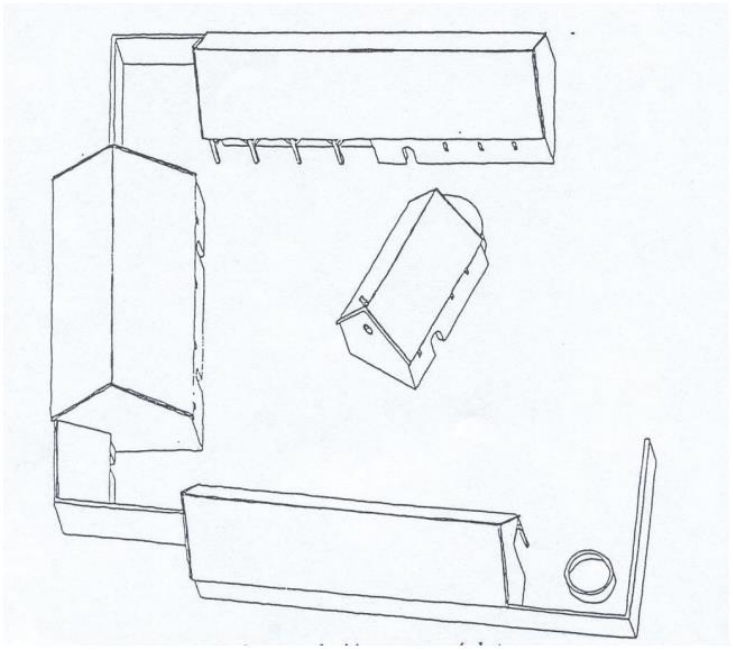


Figure 40 Reconstruction by Bálint Ásztai and Beatrix Szabó based on their survey in 1996 (Source: József Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains. The Long and Complex History of an Árpád Period Village Church," Hungarian Archeology *Winter (2014): 3.)*

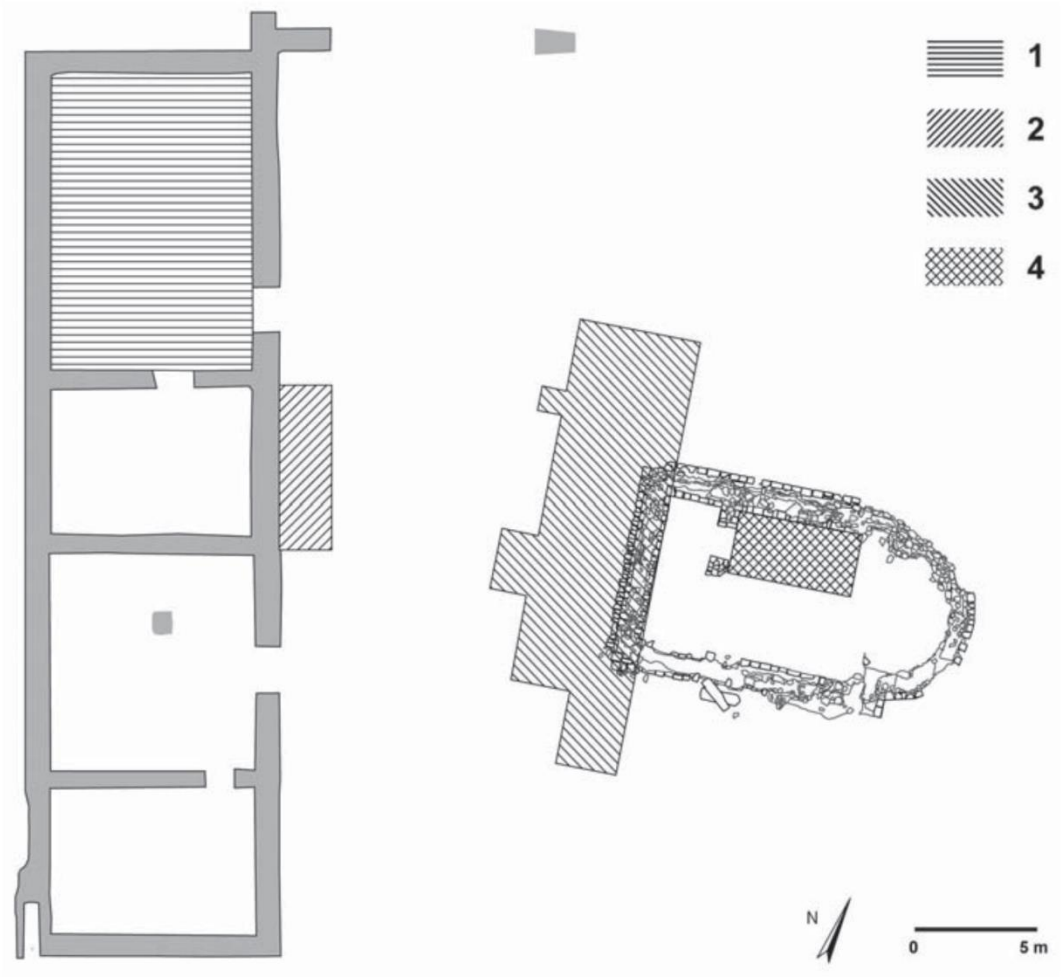


Fig. 1. Excavated areas with traces of glass production at the Pomáz-Nagykovácsi site. Workshop buildings, chapel, and the courtyard of the grange. 1: Western wing of the workshop complex, traces of kilns. 2: In front of the workshop building excavated remains of an annealing furnace. 3: Deposit of a large number of fire-resistant whole bricks and brick fragments, many with signs of burning, vitrification, and glass residue. They were moved from the workshop building and deposited in front of the chapel in the courtyard of the grange. 4: Traces of a kiln or oven identified in the church building. A burnt clay surface was excavated below a soil layer full of glass finds in the nave of the chapel.

Figure 41 *Traces of glass production at Pomáz – Nagykovácsi* (Source: *József Laszlovszky and Karen Stark, "Medieval Glass Production at Pomáz-Nagykovácsi: The Finds and Heritage Interpretation of an Archeological Site,"* Cultural Heritage Studies in Central Europe *23 (2017): 242.)*

*Figure 42 The excavated church at Pomáz-Nagykovácsi (2011) (*Source: *József Laszlovszky et al., "The 'Glass Church' in the Pilis Mountains. The Long and Complex History of an Árpád Period Village Church,"* Hungarian Archeology *Winter (2014): 5.)*

Figure 43 Remains of the western wing (Source: József Laszlovszky, "Középkori templom és üveggyártó műhely feltárása - rövid jelentés. [The excavation of a medieval church and glassmaking workshop - short report]," Altum Castrum, *2012, 3.)*

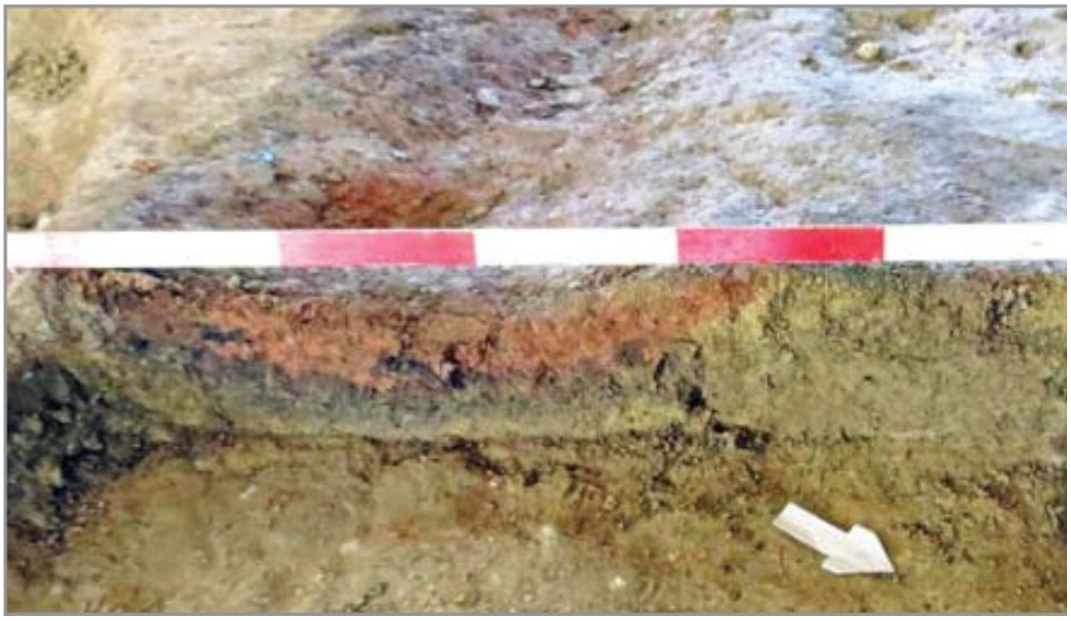


Figure 44 Burned layers connected to the melting furnace in the church (Source: József Laszlovszky, "Üveggyártás a Pilisben és egy középkori templom Pomáz-Nagykovácsi pusztán [Glassmaking in the Pilis and a medieval church in Pomáz-Nagykovácsi]," Várak, kastélyok, templomok - Évkönyv, *2015, 82.)*

Figure 45 The location of the excavated glass workshops in Visegrád on the Second Military Survey. 1, 34 Fő Street; 2, 5 Rév Street.

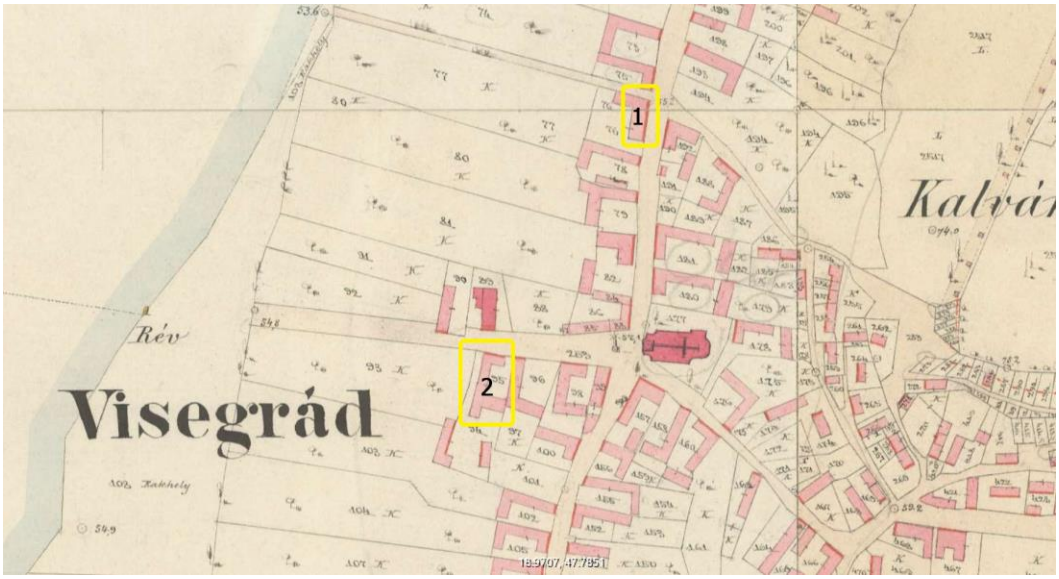
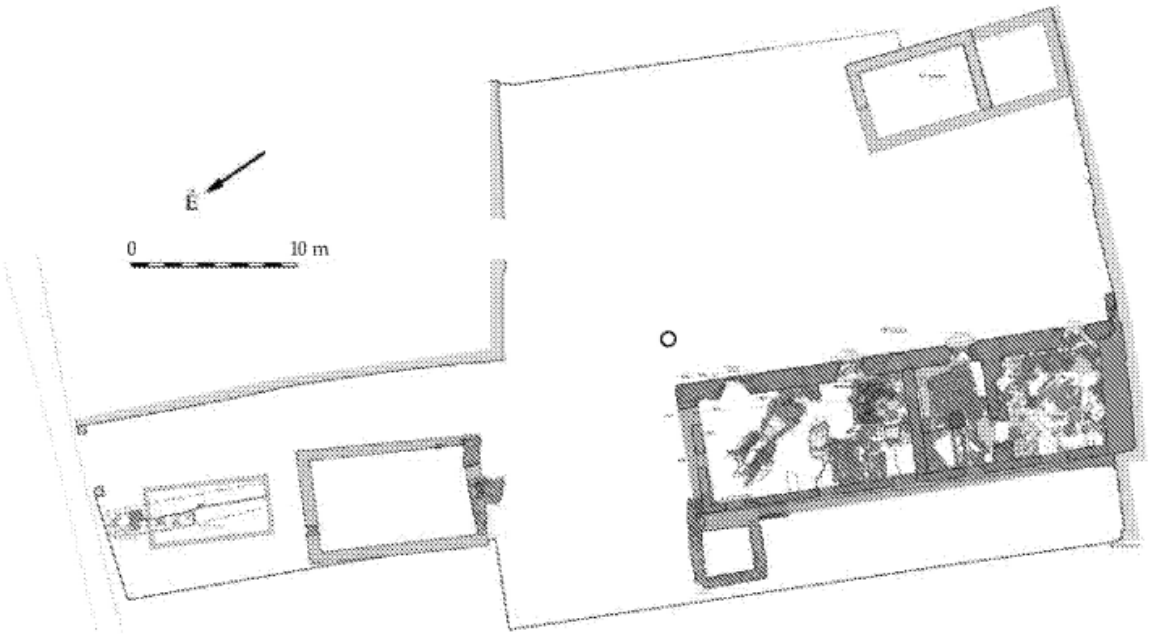


Figure 46 The location of the glass workshops in Visegrád on a nineteenth-century cadastral map 1, 34 Fő Street; 2, 5 Rév Street.



5. ábra. Visegrád-Rév utca 5. A telken talált épületmaradványok rekonstrukciója.
Rajz: Győrfy Ilona, Vajda József, Mészáros Orsolya
Fig. 5. Visegrád-Rév utca 5. Reconstruction of the building remains found on the plot.
Drawing by Ilona Győrfy, József Vajda and Orsolya Mészáros

Figure 47 The excavation ground plan of the Visegrád - 5 Rév Street plot (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon, *ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 677.)*

Figure 48 The ground plan of the glass workshop in Visegrád, 5 Rév Street (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 679.)*

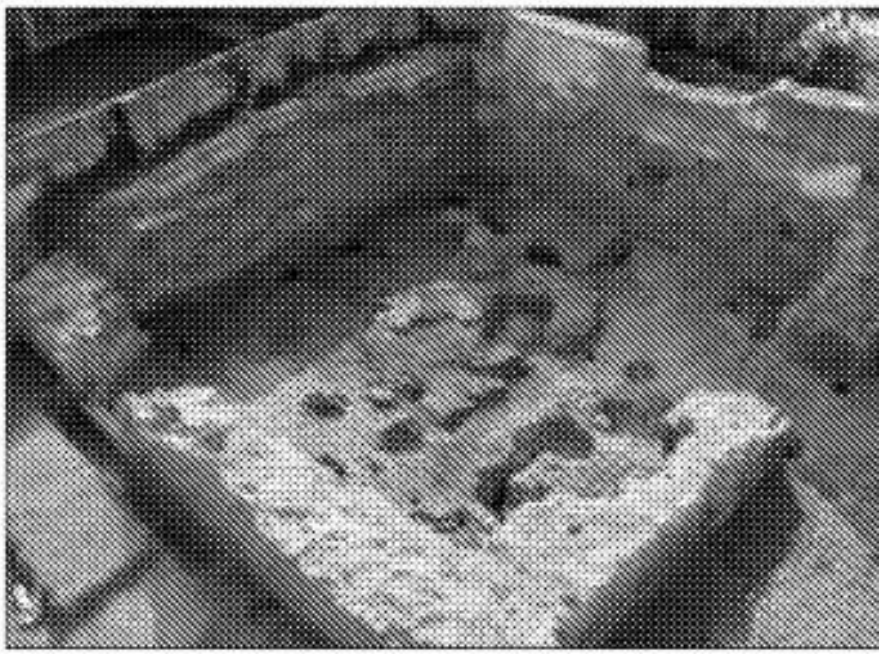


Figure 49 Room 1 of the first workshop (Visegrád - 5 Rév Street) (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 680.)*

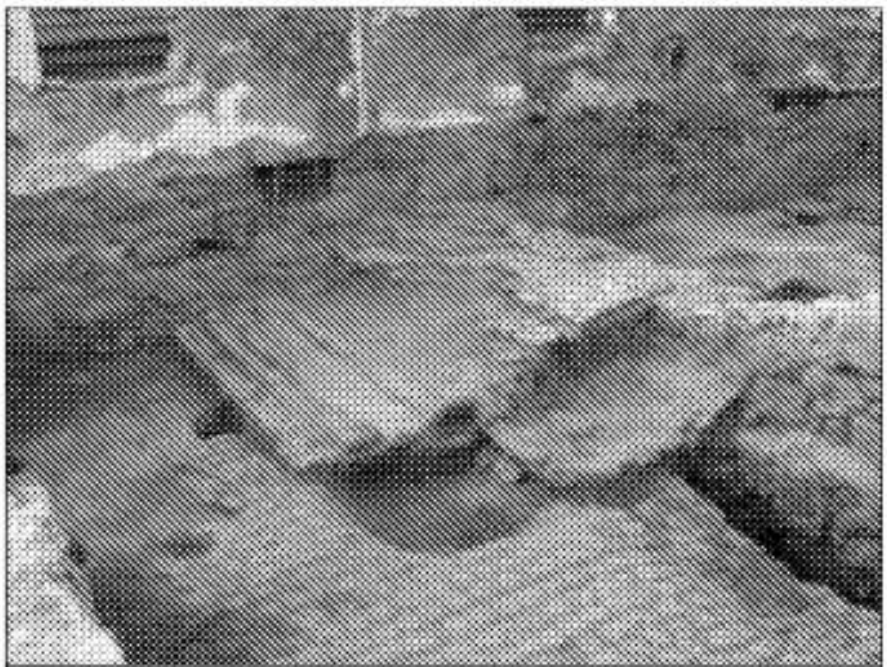


Figure 50 Room 2 of the first workshop (Visegrád - 5 Rév Street) (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 681.)*

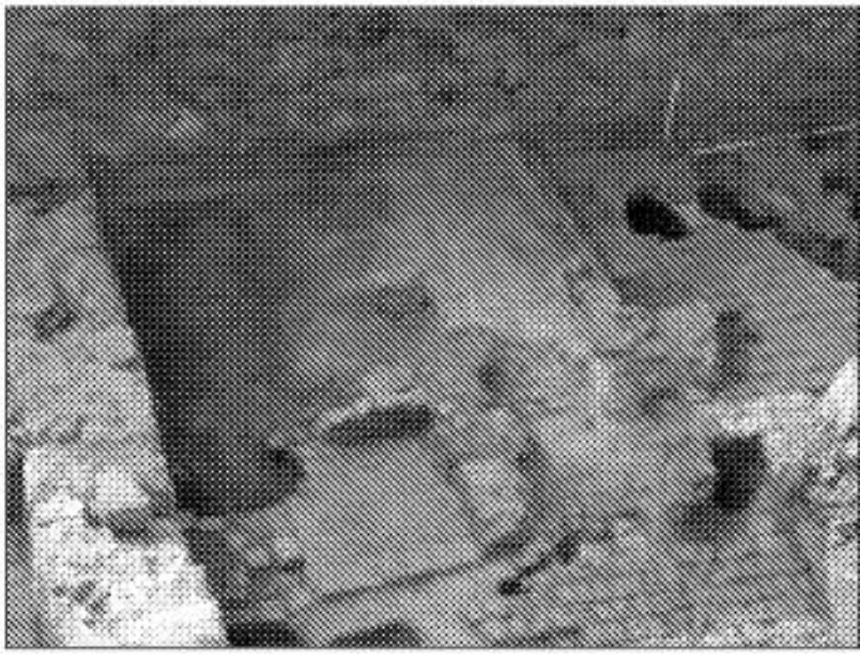


Figure 51 Room 3, part of the second workshop (Visegrád - 5 Rév Street) (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 681.)*

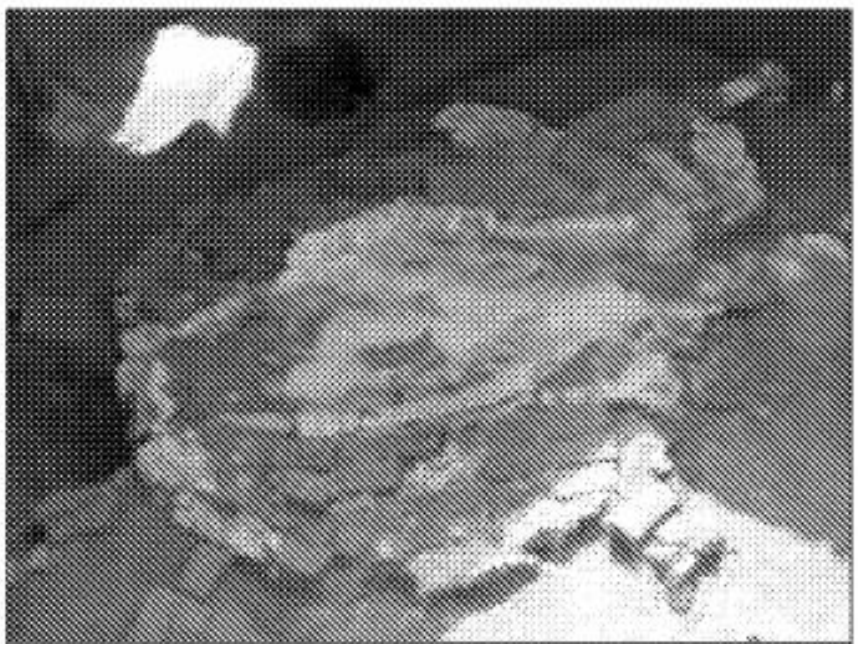


Figure 52 Oval shaped furnace of room 4, part of the second workshop (Visegrád - 5 Rév Street) (Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 682.)*

Figure 53 Ashpit, and trapezoid working space of the oval shaped furnace in room 4 (Visegrád - 5 Rév Street)(Source: Orsolya Mészáros, "15. századi városi üvegműhely és környezete Visegrádon [A fifteenth-century glass workshop and its environs in Visegrad]," in A középkor és a kora újkor régészete Magyarországon*, ed. Elek Benkő and Gyöngyi Kovács, vol. 2 (Budapest: MTA Régészeti Intézet, 2010), 682.)*

Geographical distribution of the glass workshops	
In the forest	**In the settlement**
Banská Bystrica	Buda – Felhévíz
Banská Štiavnica	Buda Castle – Northern Gate
Bardejov	Budapest – 54 Vási Street.
Bodony	Diósgyőr Castle
Budaszentlőrinc	Pásztó
Csesznek	Visegrád – 34 Fő Street
Diósgyőr - Majláth	Visegrád – 5 Rév Street
Diósjenő	Zagreb
Esztergom - Szentkirály	
Glashütten bei Schlaining	
Hoghiz	
Kremnica	
Krensdorf	
Lučatín	
Mezdev	
Pomáz - Nagykovácsi	
Râșnov	
Sklené	
Sklené Teplice	
Szatymaz - Jánosszállás	
Tălmaciu	

Table 4 The geographical distribution of the glass workshops in the Kingdom of Hungary

Social distribution / Ownership of the glass workshops				
Royal	**Nobility**	**(Medieval) citizen/craftsman**	**Monastic**	**Unknown**
Buda Castle – Northern Gate	*Sklené Teplice*	Banská Bystrica	Budaszentlőrinc	Bodony
Diósgyőr Castle	Csesznek	Banská Štiavnica	Diósgyőr - Majláth	Budapest – 54 Váci Street
Sklené Teplice	Glashütten bei Schlaining	Bardejov	Pásztó	Diósjenő
Visegrád – 34 Fő Street	Hoghiz	Buda - Felhévíz	Pomáz - Nagykovácsi	Esztergom – Szentkirály
Visegrád – 5 Rév Street	Krensdorf	Kremnica		Râșnov
	Lučatín	Mezdev		Sklené
		Tălmaciu		Szatymaz – Jánosszállás
		Zagreb		

Table 5 The different type of ownerships of glass workshops in the Kingdom of Hungary

Glass workshop	Type of products	Environment	Funder/ owner
Banská Bystrica	vessels (for gold separation)	forest, near to precious metal mine	citizens/craftsmen
Banská Štiavnica	vessels (for gold separation)	forest, near to precious metal mine	citizens/craftsmen
Bardejov	window	forest	citizens/craftsmen
Bodony	window	forest	unknown
Buda – Felhévíz	unknown	town	citizens/craftsmen
Buda Castle – Northern Gate	window, vessel	town	royal
Budapest – 54 Váci Street	unknown	town	unknown
Budaszentlőrinc	window	forest	monastic (Pauline)
Csesznek	unknown	forest	nobility
Diósgyőr - Majláth	glass slags, molten glass	forest	monastic (Pauline)
Diósgyőr Castle	window, vessel	town	royal
Diósjenő	window	forest	unknown
Esztergom - Szentkirály	glass slags, beads	forest	unknown
Glashütten bei Schlaining	window	forest	nobility
Hoghiz	vessels (for gold separation)	forest	nobility
Kremnica	vessels (for gold separation)	forest, near to precious metal mine	citizens/craftsmen
Krensdorf	possibly vessels (blue unfinished product were found)	forest	nobility
Lučatín	unknown	forest	nobility
Mezdev	unknown	forest	citizens/craftsmen
Pásztó	only glass fragments were found, possibly window	town	monastic (Benedictine)
Pomáz - Nagykovácsi	window, vessel	forest	monastic (Cistercian)
Râșnov	window	forest	unknown
Sklené		forest	unknown
Sklené Teplice	vessels (for gold separation)	forest, near to precious metal mine	royal, nobility
Szatymaz - Jánosszállás	unknown (few molten glass fragments were found)	forest	unknown
Tălmaciu	unknown	forest	citizens/craftsmen
Visegrád – 34 Fő Street	window, vessel	town	royal
Visegrád – 5 Rév Street	window, vessel	town	royal /craftsmen
Zagreb	unknown	town	citizens/craftsmen

Table 6 Distribution of glass workshops based on their environment, funder and products

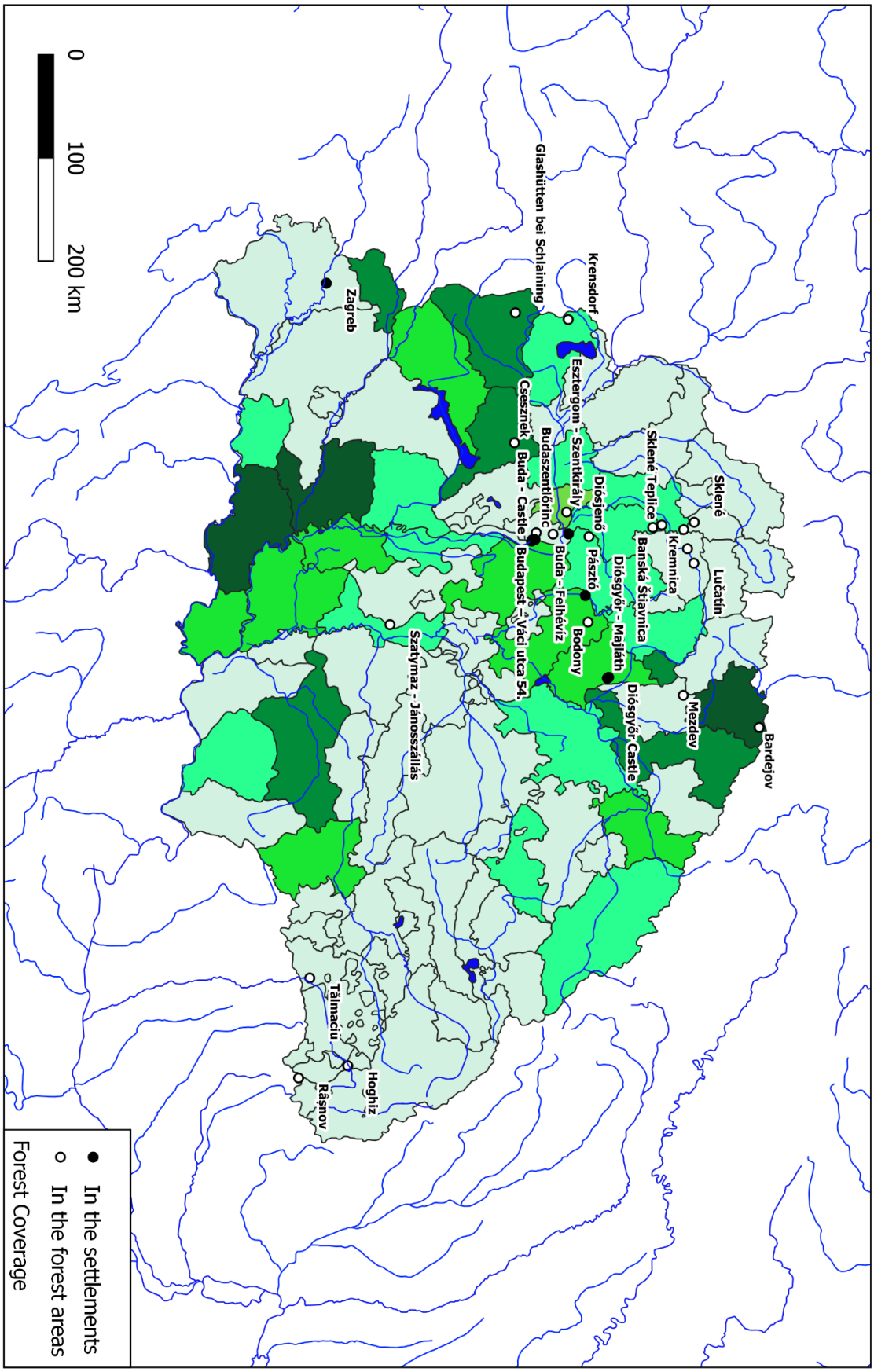


Figure 54 The geographical distribution of the glass workshops (made with QGIS by Mónika Gácsi)

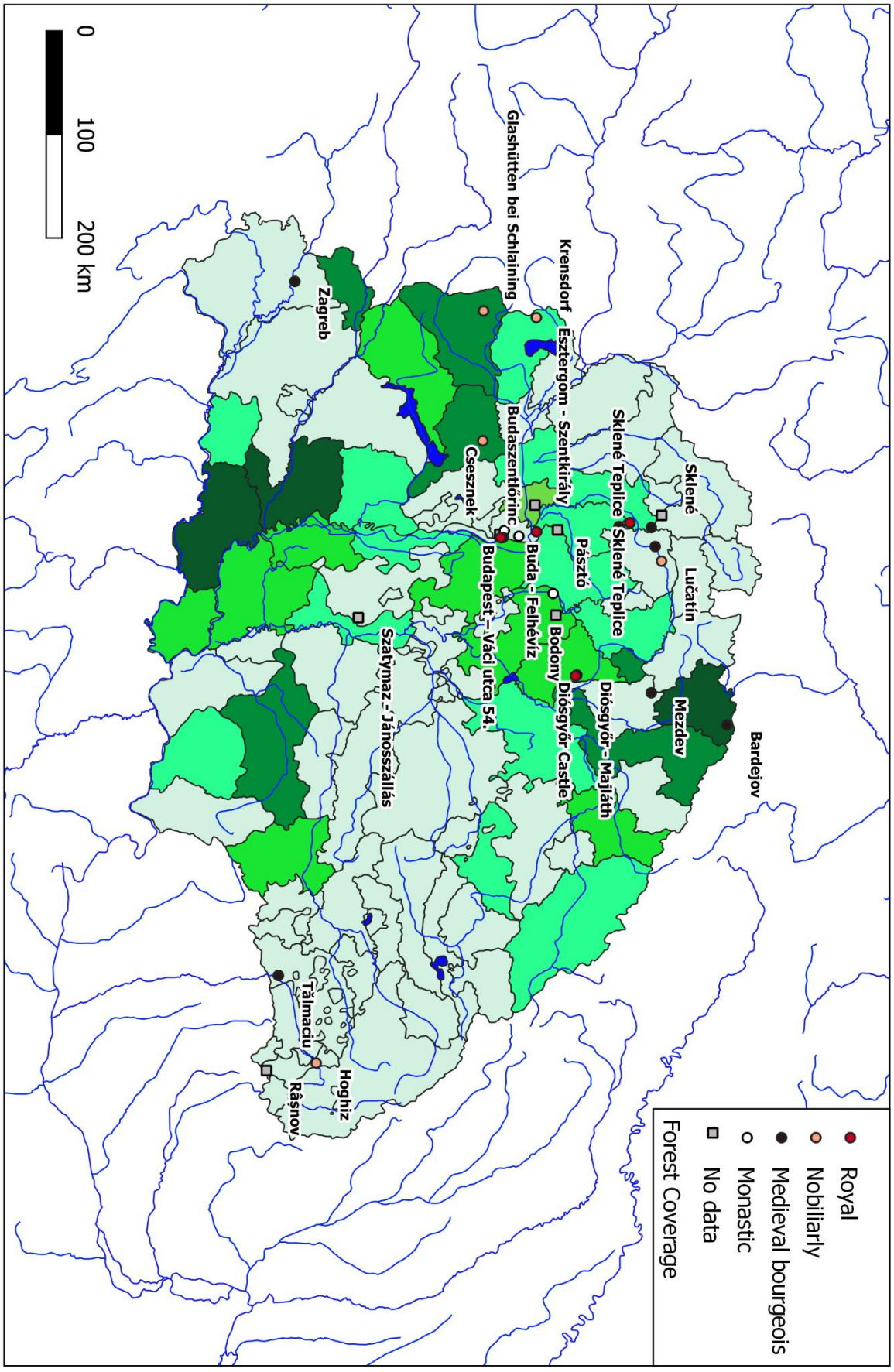


Figure 55 Typology of the glass workshops by their owners (made with QGIS by Mónika Gácsi)

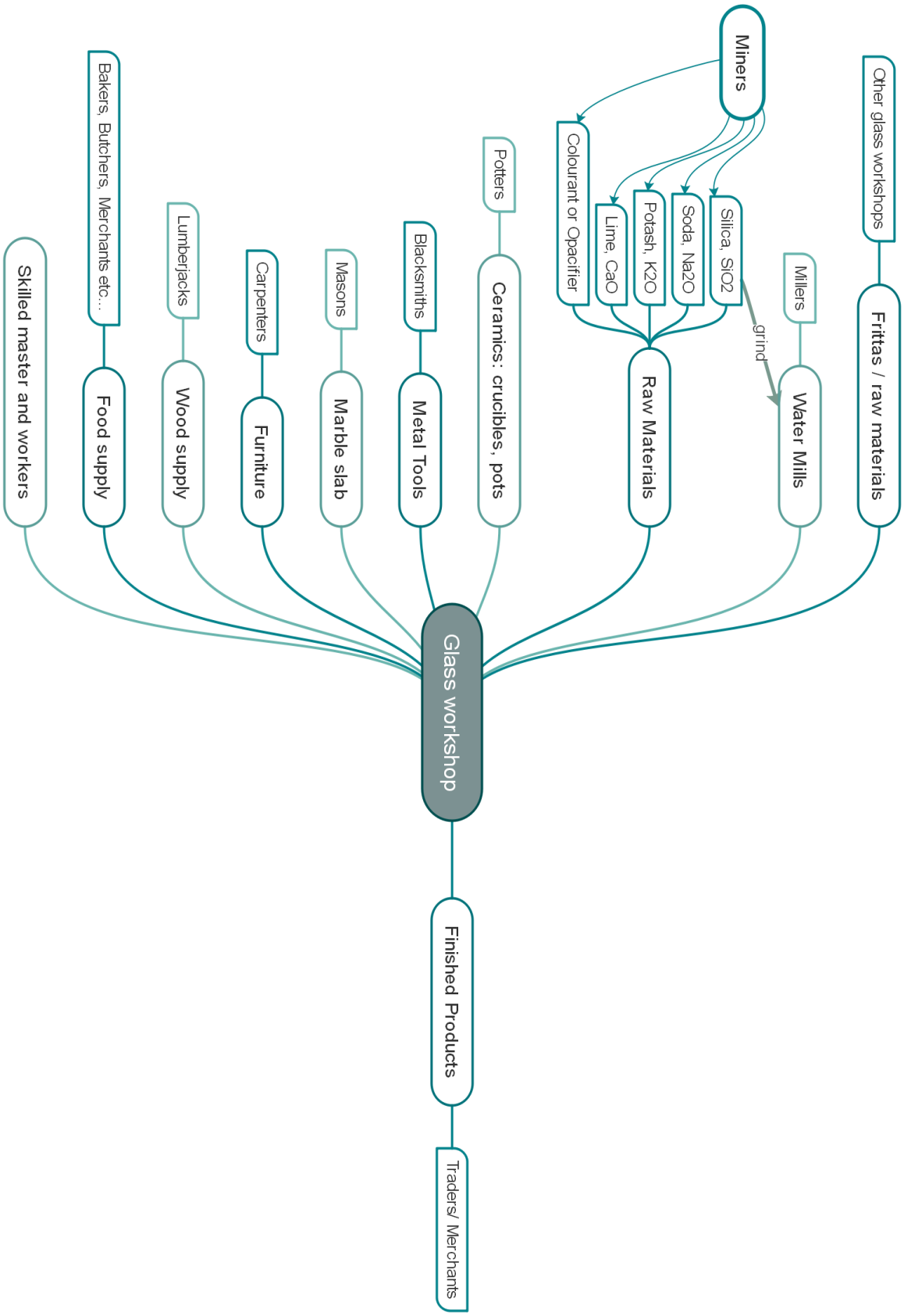


Figure 56 The needs and installation factors of a glass workshop (created by Mónika Gácsi)

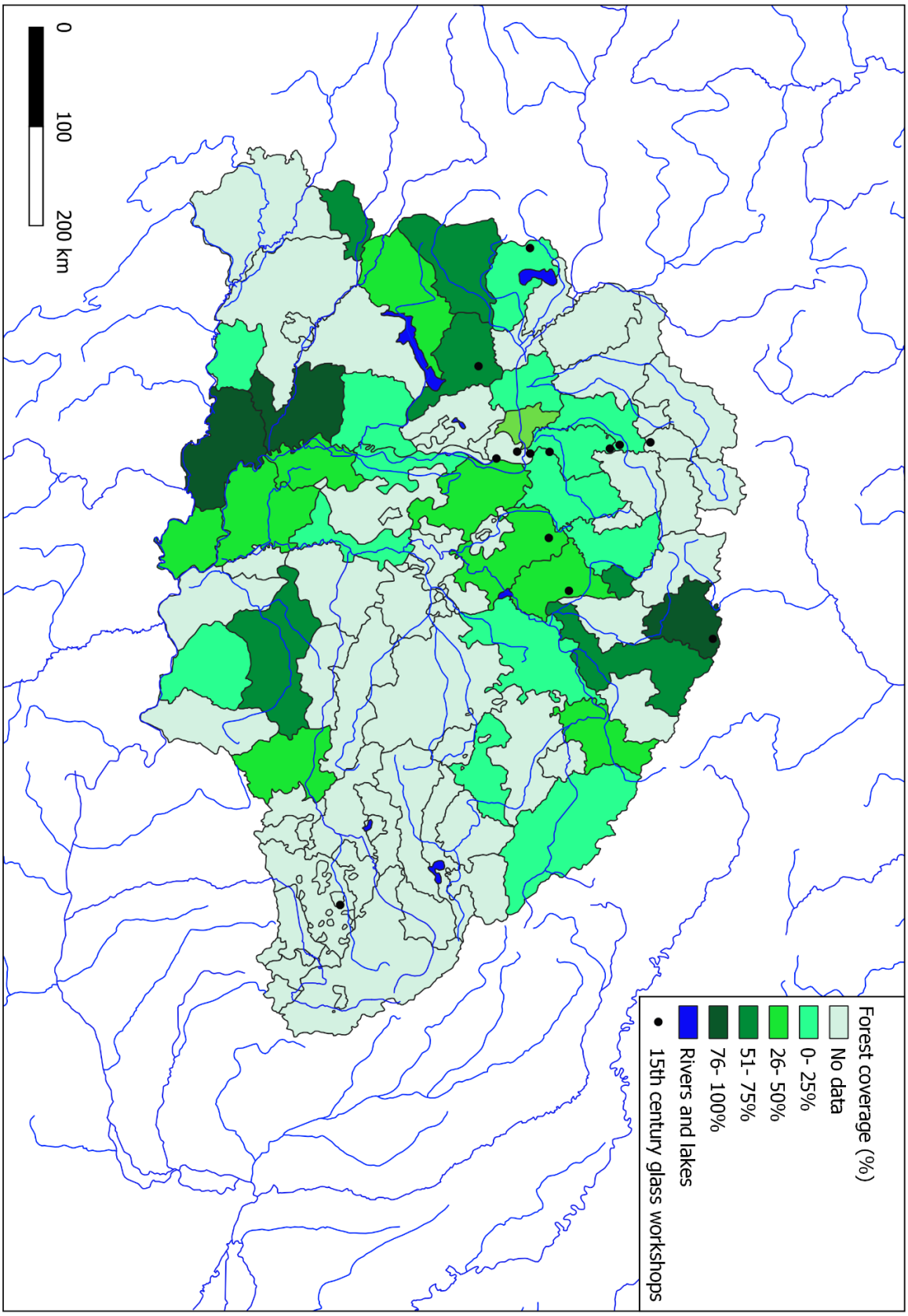


Figure 57 The connection between the glass workshops and the forest coverage in the fifteenth century (made with QGIS by Mónika Gácsi)

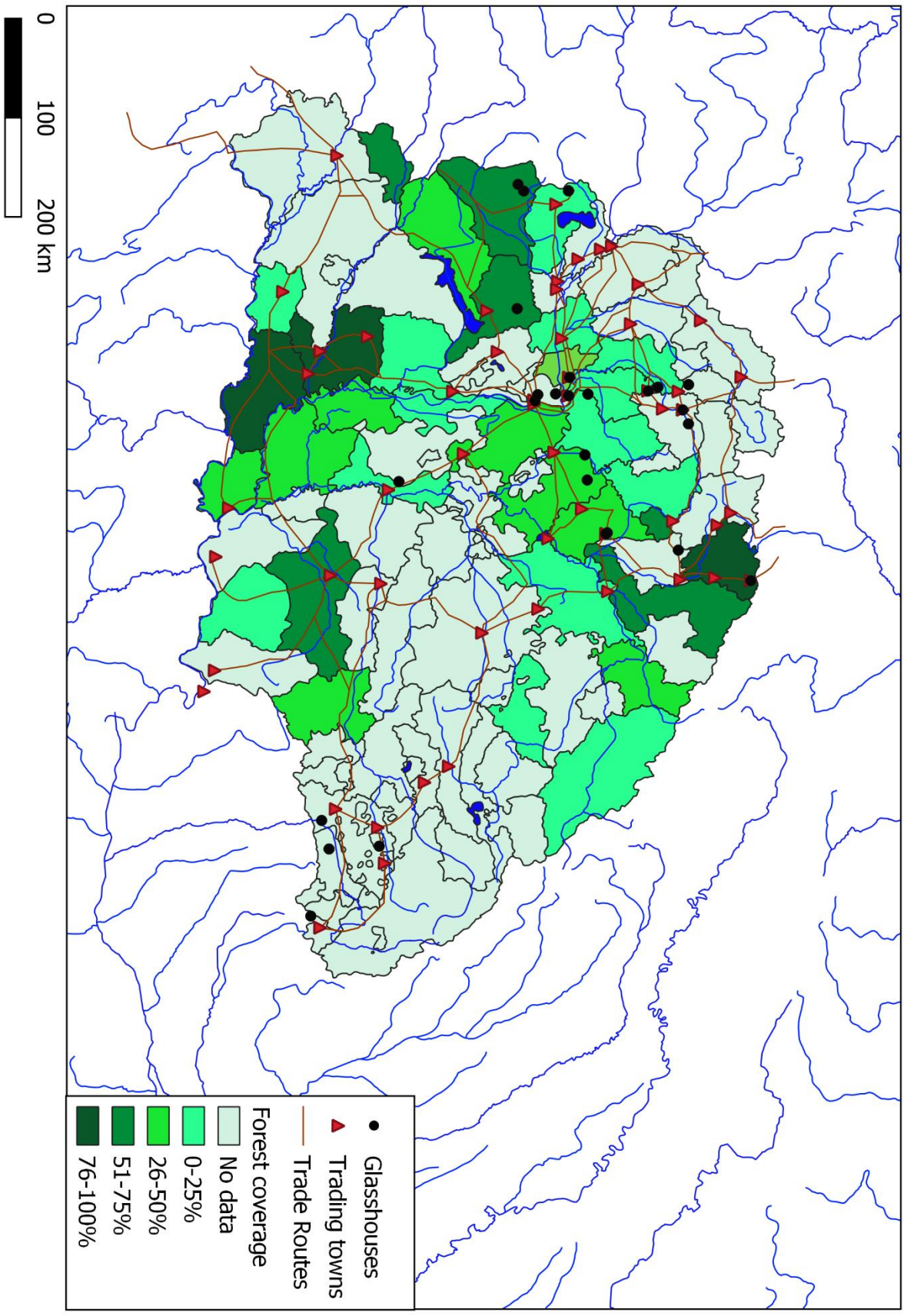


Figure 58 The connection between the trade routes and the glass workshops in the Kingdom of Hungary (made with QGIS by Mónika Gácsi)

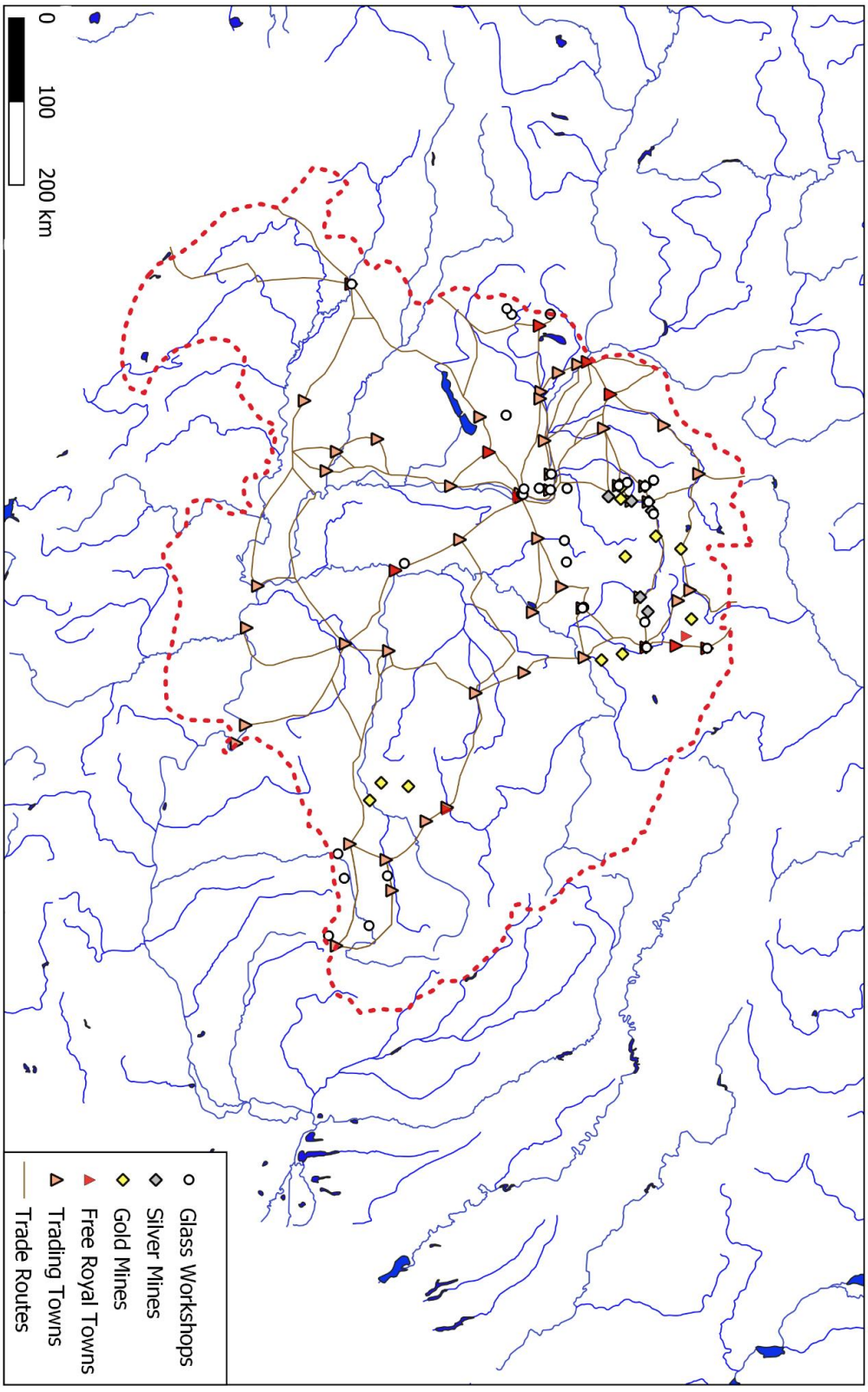


Figure 59 The connection between the settlements, mines and the glass workshops (made with QGIS by Mónika Gácsi)

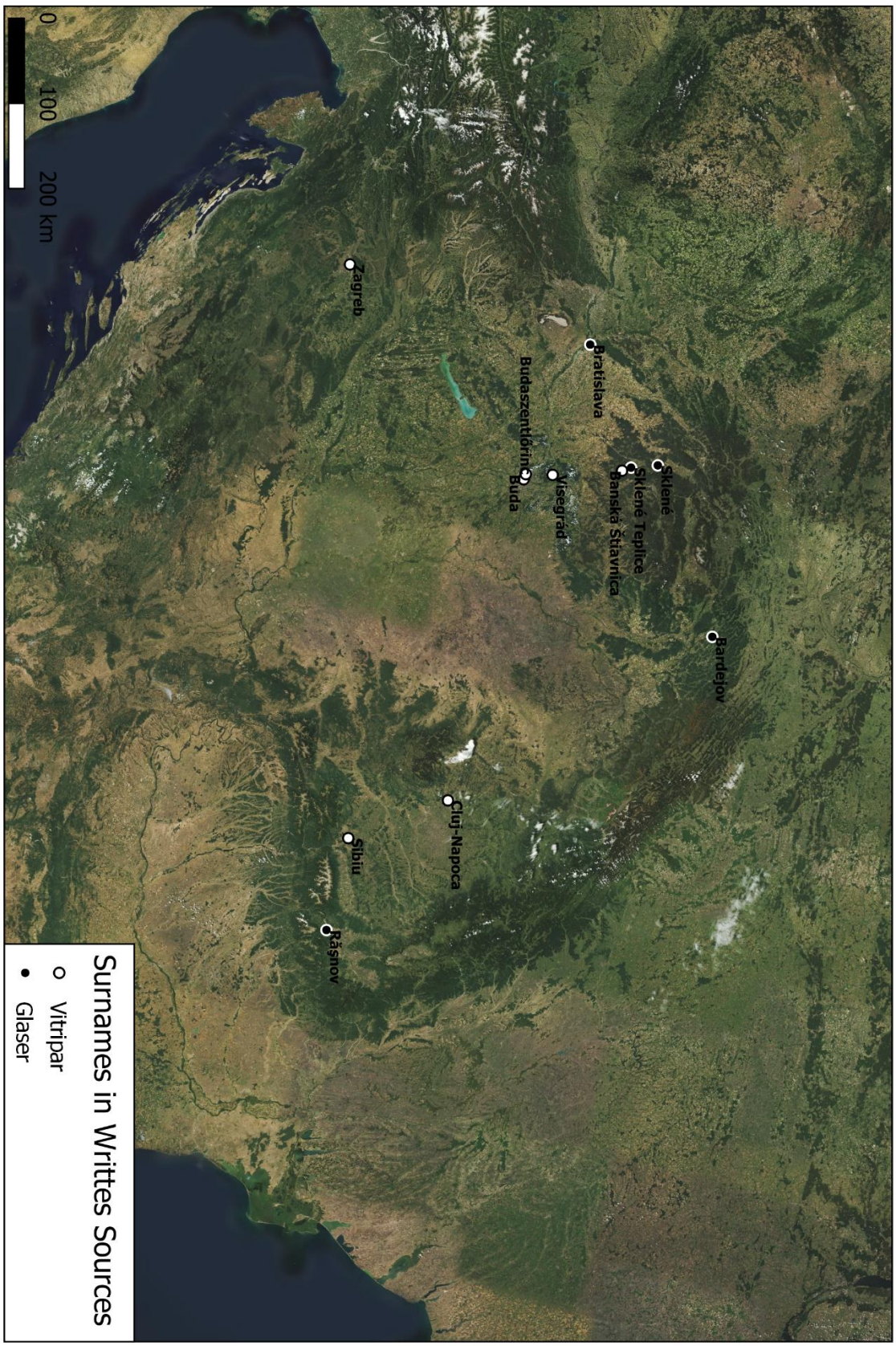


Figure 60 The geographical distribution of surnames connected to glassmaking from the written sources (made with QGIS by Mónika Gácsi)

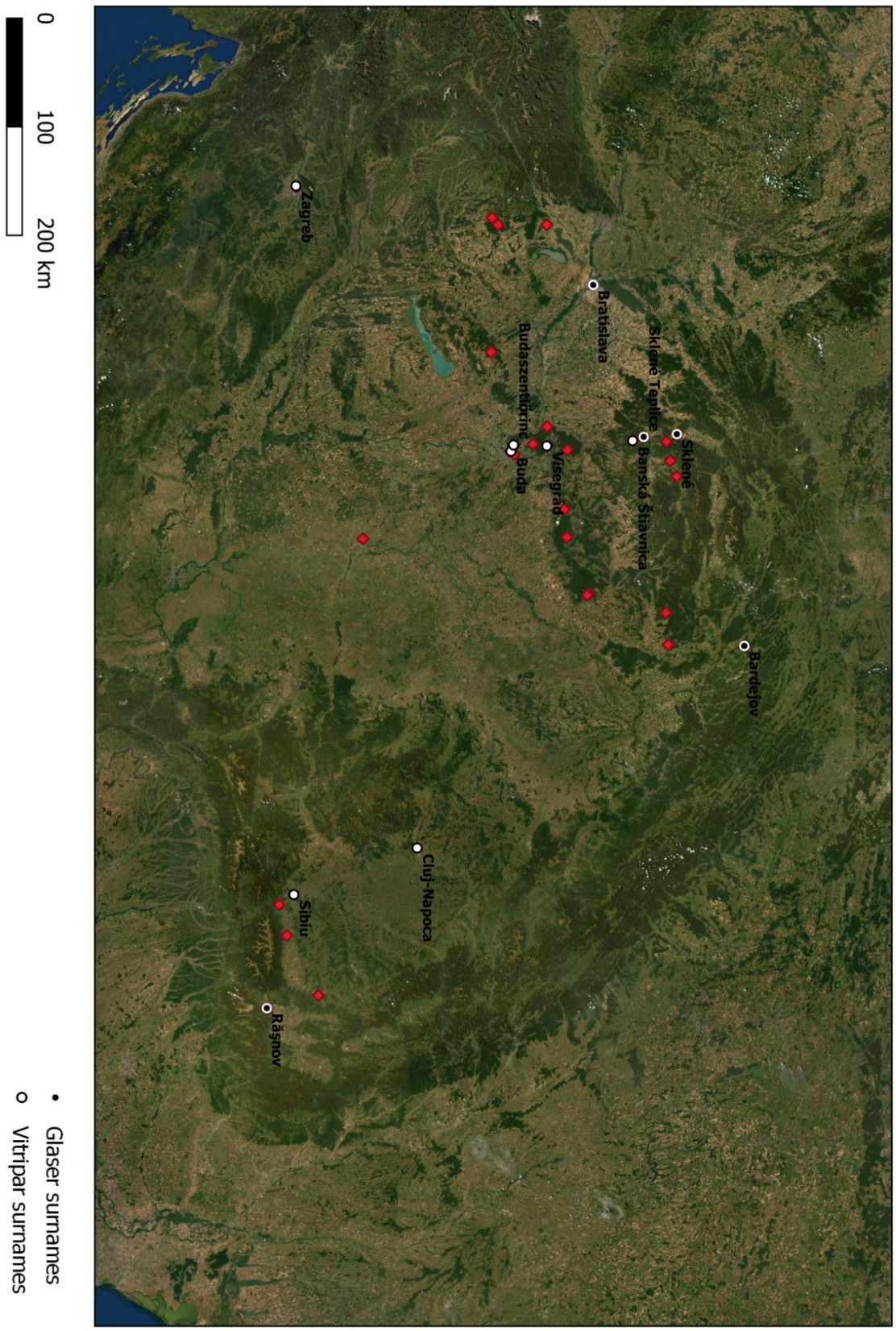


Figure 61 The correlation between names connected to glassmaking and the actual glass workshop's location (made with QGIS by Mónika Gácsi)

Workshop glossary - Name identifier

Hungarian	German	Slovakian	Romanian	Transylva-nian Saxon	Latin	Polish	Croatian
Felsőárpás	Oberarpasch	x	Arpașu de Sus	x	x	x	x
Besztercebánya	Neusohl	Banská Bystrica	x	x	Neosolium	x	x
Selmecbánya	Schemnitz	Banská Štiavnica	x	x	x	x	x
Bártfa	Bartfeld	Bardejov	x	x	Bartpha	Bardiów	x
Bodony	x	x	x	x	x	x	x
Buda - Felhévíz	Aigen	x		x			x
Budaszentlőrinc	x	x	x	x	x	x	x
Diósgyőr	x	x	x	x	x	x	x
Szalonok - Üveghuta or Szalónakhuta	Glashütten bei Schlaining	x	x	x	x	x	x
Hévíz or Olthévíz	Warmwasser	x	Hoghiz	x	x	x	x
Körmöcbánya	Kremnitz	Kremnica	x	x	x	x	x
Lucsatin or Lucató	x	Lučatín	x	x	x	x	x
Mecenzéf	Metzenseifen	Medzev	x	x	x	x	x
Rozsnyó or Barcarozsnyó	x	x	Râșnov	Rusnâ	Comidava	x	x
Szklenó or Turócnémeti	Glaserhau	Sklené	x	x	x	x	x
Bars- Szklenó or Szklenófürdő	Glasshütte	Sklenó Teplice	x	x	x	x	x
Nagytalmács	Talmesch	x	Tălmaciu	x	x	x	x
Zágráb	Agram	x	x	x	Zagrabia	x	Zagreb
Buda	Ofen	Budín	x	x	x	x	Budim
Diósgyőr - Majláth	x	x	x	x	x	x	x
Esztergom - Szentkirály	x	x	x	x	x	x	x
Tormafalu	Krensdorf	x	x	x	x	x	Kreništof
Szatymaz - Jánosszállás	x	x	x	x	x	x	x
Csesznek	x	x	x	x	x	x	x
Pomáz - Nagykovácsi	Paumasch	x	x	x	x	x	x

Visegrád	Plintenburg	Vyšehrad	x	x	Pone Navata or Altum Castrum	x	x
Pásztó	x	x	x	x	x	x	x

Table 7 Different names used for the sites (As a general practice, I used the current names of cities and settlements, as they appear in their countries.)