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14th-16th-CENTURY DANUBE FLOODS AND LONG-TERM WATER-LEVEL CHANGES IN ARCHAEOLOGICAL AND SEDIMENTARY EVIDENCE IN THE WESTERN AND CENTRAL CARPATHIAN BASIN: AN OVERVIEW WITH DOCUMENTARY COMPARISON

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Abstract

In the present paper an overview of published and unpublished results of archaeological and sedimentary investigations, predominantly reflect on 14th-16th-century changes, are provided and evidence compared to documentary information on flood events and long-term changes. Long-term changes in flood behaviour (e.g. frequency, intensity, seasonality) and average water-level conditions had long-term detectable impacts on sedimentation and fluvio-morphological processes. Moreover, the available archaeological evidence might also provide information on the reaction of the society, in the form of changes in settlement organisation, building structures and processes. At present, information is mainly available concerning the 16th, and partly to the 14th-15th centuries. These results were compared to the available documentary evidence on 14th-16th century Danube floods occurred in the Carpathian Basin.

Keywords: Danube, floods, high flood-frequency periods, 14th-16th century, sedimentary and archaeological evidence, Carpathian Basin

INTRODUCTION

The 16th century has key importance in studying and understanding medieval and early modern Danube floods. It is due to the fact that a great number of large and extraordinary flood events are known from the early, and then from the mid and late 16th century which caused severe damages along several Central European rivers (for the last systematic overview, see Brázdil et al., 1999; for extraordinary 16th-century floods in Austria, see: Rohr, 2007), including the Danube.

Due to the fact that recently a first systematic overview of documentary evidence on 14th-16th-century Danube floods in the Carpathian Basin has become mainly available in publications (for 11th-15th century evidence: Kiss, 2012a, 16th-century: Kiss, 2012b; Kiss and Laszlovszky, 2013; partly related Vadas, 2011), it is possible not only to list and discuss sedimentary and archaeological evidence on flood events, but also to find some connections and provide links between the different types of flood- and high water-level related evidence. The results of archaeological and sedimentary investigations are in good agreement with the information detectable in documentary evidence: the presently available material presumably highlights most of the great flood events of extraordinary magnitude and the most important flood waves.

Documentary evidence is mainly related to individual flood events or the relatively short-term consequences of preceding great flood events and therefore mainly provides high-frequency information. Archaeological and sedimentary evidence is mainly connected to the consequences of great or catastrophic flood events, flood-rich periods and long-term hydrological changes. Since dating of these events, periods and processes, with using natural scientific and archaeological methods, are usually possible on a multi-annual, multi-decadal level, archaeological and sedimentary data on floods are good indicators of medium- and low-frequency changes in flood behaviour. Nevertheless, documentary evidence can provide an important help in the possible more exact dating of flood events or flood peaks whose impacts could be observed in archaeological (and sedimentary) evidence (for presently available data, see: *Fig. 1*).

Beyond the application of documentary evidence, with the help of archaeological and sedimentary evidence the magnitude, long-term impacts and (materi-

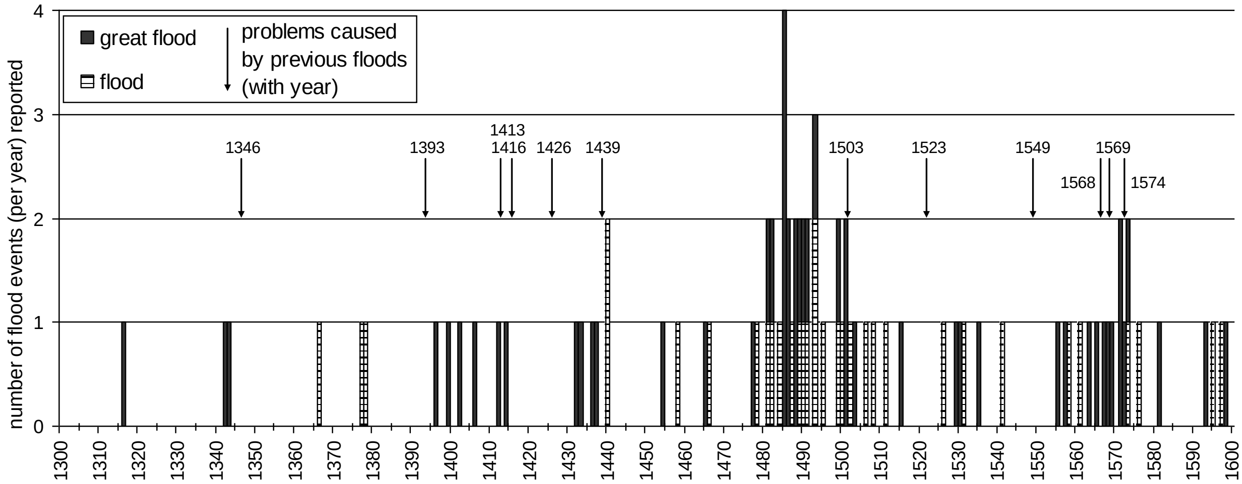

Fig. 1 14th-16th-century Danube floods in the Carpathian Basin, based on presently available documentary evidence (Sources: Kiss, 2012a, 2012b; Kiss and Laszlovszky, 2013)

al) consequences of great flood events as well as general long-term processes can be further studied in more detail.

In the present paper the published materials and scientific literature on findings in the Marchfeld and the Bratislava-Žitný ostrov area (Šamorín), the Danube Bend (Nagymaros, Visegrád, Vác), Budapest (Margit island) either as a source for further investigation (e.g. Dinnyés et al., 1993) or with further environmental interpretations (e.g. Mészáros and Serlegi, 2011) are discussed, and possible connections with documentary evidence are provided. Moreover, unpublished primary results of archaeological excavations, excavation protocols, for example, that of the Visegrád Franciscan friary are also included in the present survey. Most of the archaeological and sedimentary evidence is related to the 16th century: However, most of the processes have started already in the 14th and 15th centuries and therefore these two centuries also form an integrate part of the present discussion.

AVAILABLE SEDIMENTARY-ARCHAEOLOGICAL EVIDENCE: AN OVERVIEW OF SCIENTIFIC INVESTIGATIONS

Mid-16th century: increased Danube sedimentation at Orth – parallel changes on the Lower Morava river?

Due to its immediate vicinity to Bratislava, the available data on 15th-16th-century sedimentation conditions and changes of the Danube has crucial importance in the further understanding of contemporary flood processes. The rapid 16th-century silting-up process of a late medieval harbour, located in a fossil Danube channel, was investigated and results recently published by Fiebing and their colleagues (Fiebig et al., 2009; Thamó-Bozsó et al., 2011). The study area is located south to the town of Orth along the Danube (at the SW edge of the Marchfeld area, a former floodplain), and thus between Vienna and Bratislava (see *Fig. 2*).

Based on the dendrochronology analysis, the wooden remains of the harbour were dated between the 14th-16th centuries. Although some samples date back to the late 14th century (cutting date), most of the construction wood was cut off in the first half of the 16th century (especially between the late 1520s and 1550; see *Fig. 6* in Fiebig et al., 2009). 1550 was defined as a closing date of woods used in the construction of the harbour; the harbour was then covered by flood sediments. Of course, it does not necessary mean that the harbour was immediately given up in 1550 sharp. Nevertheless, the desertion of the harbour must have happened not much later. An interesting additional point is that the Vienna town hospital accounts – which contains information on the Danube floods disturbing or obstructing wood/timber transport – report on a Danube flood in 1548 (WStLA, Bürgerspital Bd. 26; for more source evidence and recent discussion on the consequences in Vienna, see Sonnlechner et al., 2013).

Referring to the age of the deposits (OSL dating) and that of the wooden materials, the authors concluded that a rapid infill (increased sedimentation) of the river branch around the 15th-16th centuries resulted the sudden desertion of the harbour (Thamó-Bozsó et al., 2011). For possible reasons of this rapid infill the authors suggested either the natural process of meander development or the great forest clearances of the late medieval period. In our opinion, a most likely direct factor (for the infill, and in reaching the cut-off of the meander), one or more great Danube floods or high flood frequency of the period, should be also listed among the main reasons of the rapid infill process of the harbour and the Danube channel.

Applying early maps, similar changes from the second half of the 16th-century were also mentioned by hydromorphologists, for example, concerning the cut of a Danube meander at Wolfsthal, probably preceded by a flood event or a series of events (Pišút, 2005; Pišút and Tímár, 2009). The historian, Sándor Takáts (apart from several references on destructive mid and late 16th-century ice flows) also mentioned such a case, namely that a harbour and main toll place, dated from high medieval times, was moved away from its original location

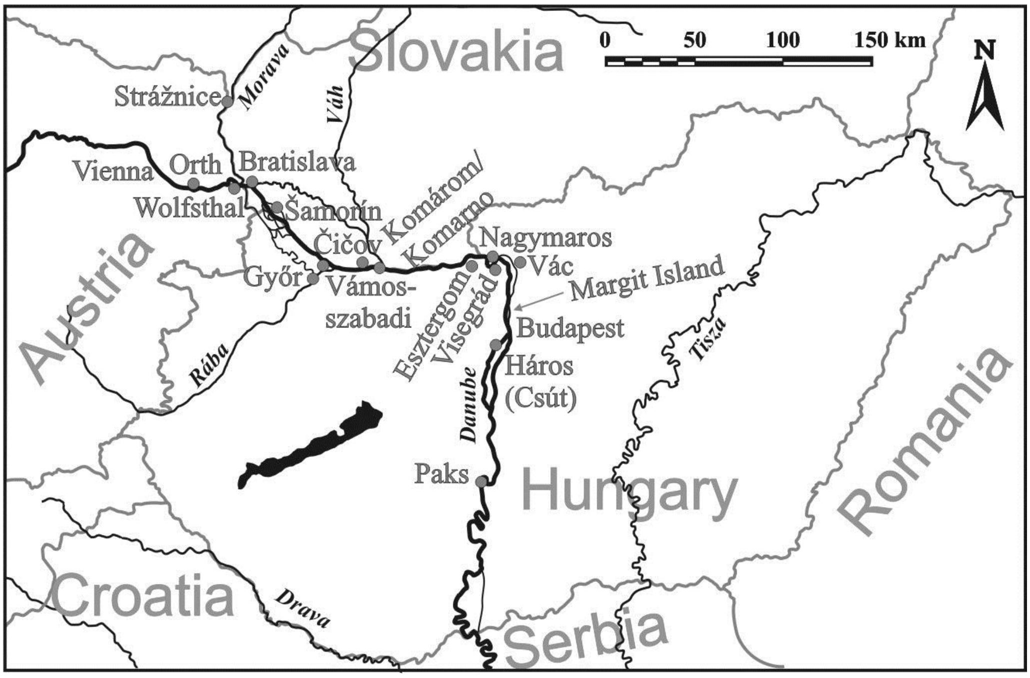

Fig. 2 Locations mentioned in the present paper

to Komárom (from historical Csicsó – today Čičov in Slovakia, in the Žitný ostrov: see *Fig. 1*) in the early 16^{th} century, and its harbour and foreground was filled up with Danube flood sediments (Takáts, 1898).

As a possible parallel, described in an official letter in 1549, short before the Danube at Bratislava also partly changed its bed, and floods were actively damaging the town walls (see Kiss, 1908; for more details see: Kiss, 2012b). Concerning this case, Ortvay (1912) suggested that – similarly to the cases described by Fieber and his colleagues at Orth – an avulsion of the Danube channel occured at Bratislava, and made the town walls (which were anyway in bad condition) more prone to destructive flood events. It is quite probable that this later event had connections to the great 1548 flood in Vienna mentioned above. Moreover, a number of flood events were also reported in contemporary documentation concerning the 1550s, and the great floods occurred practically in each year around the turn of the 1560s and 1570s (see *Fig. 1*).

Another important investigation on river sediments was carried out, practically in the same time, on the lower sections of the Morava River, an important tributary of the Danube, entering the river just before Bratislava. According to the study, a substantial change occurred in the character of flood sedimentation (from clay-dominated layers to layers with more sandy and silty character) around 1550 (and/or the decades around). Prior to this date, the authors also detected another period of increased fluvial activity which, based on the flood catastrophe and its hydromorphological consequences, reconstructed by Bork (1989), they connected to the 14th-century period and the 1342 flood event (Kadlec et al., 2009). In another study concerning the same area it was concluded that two most important changes in river channel structure occurred in the 13^{th} century and in the second half of the 16^{th} century (1550-1600; see Grygar et al., 2011). An interesting additional information might be that, according to Takáts (1898), in 1573 the Morava river left its bed at Ungernsdorf; because of this change, the mills of Marchegg could not be used any more.

Since the Morava River collects the waters in the Moravian Basin, and then enters the Danube close to Bratislava, parallel processes, occurred in the 16th century (especially in the mid 16^{th} century) suggest large-scale changes in the flood behaviour of the river. Moreover, it also suggests that these processes, namely the high flood frequency on the River Morava in the second half of the 16th century, could be detected approximately in the same time on the Danube close to Bratislava (most data in *Fig. 1* is originated from the Bratislava area; see Kiss 2012b) and on its important tributary. Based on documentary evidence, this mid and late 16^{th}-century flood peak was also detected on both the German (e.g. Lech, Isar, partly the Inn; see Böhm-Wetzel, 2006) and the Austrian tributaries of the Danube, and also on the Upper Danube itself (Traun: Rohr, 2006; Danube: Rohr, 2007; Glaser, 2008; Sonnlechner et al., 2013).

It is an interesting, additional information that the importance of the mid and late 16^{th} century in studying historical soil erosion caused by water has not yet been detected in Germany (including Southern Germany). According to the authors of the latest overview, from the high medieval period onwards, only two weak maxima could be traced: one around 1200-1400, with special emphasis on the disastrous 14^{th}-century events culminating around 1342, and another around 2-3 centuries ago, with special emphasis on the late 18^{th}-early 19^{th} century. These interim results, however, might underestimate soil erosion intensity in the medieval and early modern-modern period, due to the low number of dated colluvial layers (see Dreibrodt et al., 2010).

(14th-)16th-century changes in Šamorín: a prosperous town in dangerous location?

In the late medieval town of Šamorín (historical Somorja; see *Fig. 2*) in the Žitný ostrov (historical Csallóköz; island area east to Bratislava, in South-Slovakia) two main building periods were distinguished by archaeological excavations (Urminský, 2005). One of them took place after the destruction of the high medieval wooden structures (in a flood-risk area of Danube branches) in the second half of the 14th century when, together with a change in building material from the wooden-clay structure to brick (at least at the foundations), in the yards of houses (located on a slope descending from the loess terrain) along the main street of the settlement a 0.5 m ground-level rise could be detected. Another turning point occurred around the end of the 15th and beginning of the 16th century. On the main street of the town (Fő utca) new building process was started: in this case the feature of the yards was 'radically' changed: the ground level of the yards was raised with around 1.5 m.

As a documentary parallel, mainly based on the flood-related information preserved in the Bratislava accounts a rather significant flood peak was detected in the late 15th and early 16th century (see *Fig. 1*): starting from the end of the 1470s, in the decades of the 1480s, 1490s and 1500s great and destructive floods and ice flows (and ice floods) occurred at least in every other year, sometimes more than one within a year (e.g. 4 great floods in 1485; for detailed information on documentary evidence, see Kiss and Laszlovszky, 2013). This flood peak, otherwise, quite distinctively appears also on the flood frequency diagrams of the Bavarian Danube tributaries (see Böhm and Wetzel, 2006).

Due to their potential consequences, it is worth to refer to the greatest flood events in particular. In Austria, including the Vienna area, the "deluge" in 1501 (August) was the largest reported flood event on the Danube; it was estimated to be significantly larger than the great flood event of 2002 (e.g. Rohr, 2007; http://www.wien.gv.at), or the ones occurred in 1899 and 1954 (Kresser, 1957). Concerning the Carpathian Basin, a rather clear source refers to this flood event: the inhabitants of Vámos(szabadi – see *Fig. 1*) in the Szigetköz island area, close to Győr (thus, southeast to Šamorín, on the opposite side of the Danube), were allowed to pay half of the tax due on Saint George's Day (24 April) in 1502 because of their need/poorness caused by the "deluge" ("*dilu*(v)*ium aque*"; source: HNA DF 279560). It seems, however, that a significant flood event already occurred on the Danube at Bratislava earlier, in May; while some of the flood damages were reported in late October (HNA DF 240953, 277113). Additionally, a royal charter provides a testimony that the problem of frequent floods caused severe, constant problems for the inhabitants of Bratislava by 1503 (HNA DF 240970; see *Fig. 1*). 1503 in itself is also interesting because, apart from 1501 and 1508, this was another major flood year on the Danube tributaries (see e.g. Rohr, 2007).

The other great (double-)flood event in Austria occurred in 1508. At the moment, information concerning the magnitude of the 1508 flood event in Hungary is available only in indirect evidence: the flood mark of the 1508 flood event (although the newspapers refers to 1509) on a tower of the Győr was still seen and compared to some 18th-century flood marks (1768-referred as 1769 and 1784), in which case the flood level of the 1508 event was above the maximum level of the other two, 18th-century levels (see Magyar Hirmondó 27 March 1784, No. 24; Kiss, 2012b). It is also an interesting question why the 1508 flood mark was reported and no any reference was mentioned on any possible 1501 flood mark.

There is no direct evidence available whether or not these changes were connected to any flood problem. However, it is still an interesting fact that especially the second, 'drastic' ground-level rise occurred – parallel to the building processes and changes observed at the Margit island and also in Visegrád – exactly in the same period when the important late 15th–early 16th-century flood peak and the two catastrophic Danube floods (1501, 1508 and perhaps also 1503) took place. Thus, even if the new building process in Šamorín could also accidentally occur in the same time when large Danube flood events took place – for, example, elevation changes in ground level can be also detected along the Danube in less flood endangered location (e.g. the resettling process of the village of Csöt/Csút at Budafok-Háros; see: Irásné, 2004a and *Fig. 1*) –, the destructive flood events might have had some impact on how the new ground levels, the settlement and building constructions developed. Thus, it is an interesting coincidence or probably more than a mere coincidence that since the second half of the 14th century (when otherwise the wooden structures were also destroyed) exactly around the turn of the 15th–16th centuries arrived the time when significant and extensive earthworks (great rise of ground level of the yards) were carried out.

The question might have some further important aspects: Šamorín is the interesting case which was mentioned in late medieval–early modern documentary evidence concerning early flood protection works. In this respect, both in 1426 and in 1569 the flood danger and damages affecting the town's cultivated lands (and also the entire Žitný ostrov area) were mentioned as a chief problem and the main reason for large-scale flood protection works (Kiss, 2012a,b). However, in these cases, either in the form of a direct royal order or a parliament decision, the damages and losses of the cultivated lands, and not the damages occurred in the town (i.e. buildings, inhabitants) were emphasised. It might also be an interesting parallel that, while a significant rise of ground level occurred in the yards, no elevation change of the main street and the ground level of houses took place around the turn of the 15th and 16th centuries.

Gravel-loess layer as a trace of major 16th century flood(s)? Nagymaros in the Danube Bend

According to András Pálóczi Horváth, a great 16th-century Danube flood left a distinct gravel layer (mixed with loess) over the 15th–16th-century pottery and (early and late) 15th-century coins in the market town of Nagymaros (opposite to Visegrád), in a depth of 110 cm. Regardless of which flood event or events caused this gravel-loess layer, it had to be a major event or set of events: the appearance and large quantity (dominance) of gravel in the layer may suggest increased sediment-carrying capacity, which is typical for flood events with great discharge (see e.g. Nagyváradi, 2004). Moreover, due to the relatively high level of this significant river sediment, this flood event (or events) could be comparable in height to the great 20th- and early 21st-century Danube floods.

Above the gravel-loess layer, a mixed layer was found with 14th–17th-century remains (report published in: Dinnyés et al., 1993). It has to be noted that the Nagymaros side is the side where Danube sediments (especially rough sediments) are predominantly settled down by the river (it is dependent on the geo- and hydromorphological conditions, and did not fundamentally change up to the present times). Thus, especially rough sediments of Danube floods are much more likely to appear in the Nagymaros area than at Visegrád. As we will see later, several rather interesting features (e.g. fine sediments), presumably related to Danube flood event(s), indeed were identified in Visegrád.

In case of Nagymaros, the predominantly 15th-century archaeological evidence was found as a separate (undisturbed) layer under the gravel-loess layer, which indirectly suggests that the previous layer had enough time to settle down and the following flood event already could not significantly disturb this late medieval layer. Moreover, taking other Danube sedimentary flood investigations into account (e.g. the investigations at Paks, see Nagyváradi, 2004), the gravel-loess layer could develop after a single flood event, or as a result of not only one, but a series of flood events.

As for dating the flood event, applying the parallel observations carried out in Vác and with reference to climatic change, Mészáros and Serlegi suggested that the flood had to occur during the Turkish occupation and thus, not before the mid-16th century (Mészáros and Serlegi, 2011). Since a major flood period occurred on the Danube in the second half of the 16th century (see e.g. Kiss, 2012b), it is possible that this flood layer developed around the mid or late 16th century. Nevertheless, the archaeological dating of the layer located underneath the gravel-loess layer (and so as the mixed 14th–17th-century infill) in itself may also allow an earlier dating for the disastrous flood event(s): this/these could, for example, also happen in the middle of the century, or even before (i.e. 1501, 1508 or 1515, for example, cannot be excluded either).

In documentary evidence, the mid 16th century is characterised by great flood event(s) before 1549 prior to 1549, the consequences of great flood event at Bratislava. Moreover, damaging floods, reported prior to 1555, were probably also mentioned at Komárom together with 1557 and 1558 flood events at Bratislava. Then the flood series of the 1560s has to be considered: the great flood events, especially from 1567 (for Austria, see Rohr 2007), in the late 1560s (1568, 1569) and early 1570s (great flood events occurred almost every year: see Kiss, 2012b) caused long-term, irreversible changes, for example, in the Bratislava and Žitný ostrov area (e.g. lands swept away, reported in 1574: Maksay, 1959) and can be considered as floods of extraordinary magnitude (for destructions in Austria and Vienna, see: Rohr, 2007; Sonnlechner et al., 2013). Moreover, based on documentary evidence, we have to consider another peak of frequent and great flood events in the late 16th and the early 17th century, detectable in the Komárom area (see e.g. HNA, UC 86: 10, Király, 1890; for further overview, see: Kiss, 2012b).

Long-term processes: rising Danube water level at Visegrád in the late medieval–early modern times

A long-term process, affecting settlement and building conditions even in the late medieval–early modern period, was observed at the urban excavations of Visegrád. Here a clear water-level rise of the Danube occurred between the 13th and the 16th centuries, first detected by Miklós Héjj. He also raised attention to large-scale human impact on the Danube catchment area as a potential reason for increased rise of Danube water levels. Miklós Héjj's investigations of settlement development, based on the excavations of the medieval royal centre and civil town of Visegrád, suggested a long-term rise of Danube (high or flood) water levels (in its Danube Bend section) from the 13th century onwards (Héjj, 1988). As a consequence of this process, we have to consider that the (high or flood) level of the Danube might have been lower in the Middle Ages than it is today (Mészáros, 2006). Additionally, due to the extensive excavations of the royal palace complex and the settlement itself, concerning the rise of ground levels in different periods, a more detailed analysis can be provided.

Visegrád town: Late 15th–early 16th-century cellar infill due to floods

Even more specific flood-related evidence has been recently published referring to some of the urban excavation sites: located in the present-day school yard, under the 18th-century features a 14th-century building was excavated. The cellar of this late-medieval building was filled up at the end of the 15th or beginning of the 16th century, presumably due to flood problems. This theory of the excavating archaeologists was supported by the fine sediment (mud) layers settled by flood water, found in the same cellar underneath the artificial infill (Kováts, 2013).

The archaeological data on late 15th–early 16th-century floods is in good agreement with the information detected in documentary evidence: one of the most important (and certainly best documented) medieval flood peaks took place exactly around the decades of the 1480s, 1490s and 1500s (see *Fig. 1*).

All in one? 14th–16th-century flood processes and the Franciscan friary in Visegrád

Excavations carried out in recent years at the site of the medieval Franciscan friary (built in the 1420s), located close to the Danube on a gentle slope, provide us with further evidence (Buzás et al., 1995; Laszlovszky, 2009, 2013). Since some important parts of the excavation results are yet unpublished, and also due to the fact that in this case practically all the 14th–16th-century processes, described in other cases, could be detected, related information on the excavation site and the identified processes are discussed here in more detail.

In this case at least two (or three) different processes could be identified. One was the general rise of the ground levels, which process can be clearly detected from the 14th century: the remains of the earlier settlement were located around two meters underneath the friary, but especially under the cloister built in the 1420s (during the late 14th–early 15th-century flood peak: Kiss 2011; for great Danube floods in the Carpathian Basin see *Fig. 1*, and Kiss, 2012a; for the Eastern Alpine Region: Rohr, 2007). When the friary was founded, a big (double-)cellar was built on the western (Danube) side of the cloister: one under the kitchen and the other under the refenctury (*Fig. 3*). In this case, in order to compensate the slope of the terrain, the builders raised the ground level. At the same time, the floor level of the previously mentioned double cellar was roughly the same as the floor level of the houses of the 14th-century settlement, replaced by the building complex of the Franciscan friary (Laszlovszky, 2009, 2013).

Two re-building phases were also detected during the archaeological investigation of the friary. One of them took place during the Matthias-period (1458-1490, with a building activity ca. 1470-80s), while the larger, almost total re-building of the complex happened during the first decade of the 16th century. During this new building phase, another significant rise of the ground level was initiated, which can be clearly detected in the layers of the cloister garth and under the pavement of the cloister walk. Already in this phase one of the two cellars in the western wing, under the newly constructed kitchen has been filled up with earth and a small new cellar was erected in the eastern wing of the cloister, close to the hill slope, behind the building complex (see *Fig. 3*).

The other process detected is related to the cellar under the refectory: during another early 16th-century building process the remaining cellar, located in the western, Danube side of the friary under the refectory, was filled up and a new cellar was built on the opposite (eastern) side of the friary in a safer location, carved into the rock of the slope of the hill and far from the river.

During the building process, in 1511 the Franciscans received permission to use the stones of the Saint George chapel in building the new tower of the friary (Buzás et al., 1995). The re-building process must have been finished by May 1513, when the congregation of the observant province took place in the friary.

One year later (May 1514) another congregation of the observant leaders took place in the friary: in this case with the task of electing the delegates who could go to Assisi for the general chapter. The friary clearly had to be in 'good shape' in 1513 and 1514 when the important personalities arrived and stayed there for the congregations. The next important information is known from 1540: in this year, due to the siege of the lower (royal) castle, the friary was damaged, and then, after the Turkish occupation, by 1544 the Franciscans left the friary forever (Buzás et al., 1995).

Nevertheless, some time between these two dates, namely between 1514 and 1540 something (serious) happened in the environment of the friary, because one part of the building, namely the northern cloister walk (with pavement, pillars, vaulting etc.; for location, see *Fig. 3*) sank down with one meter, and because of this great change, the Gothic vault of the corridor has collapsed. When rebuilt, no vaulted structure was constructed, but most probably a simple horizontal wooden ceiling was used to cover the northern corridor. The infill of the for-

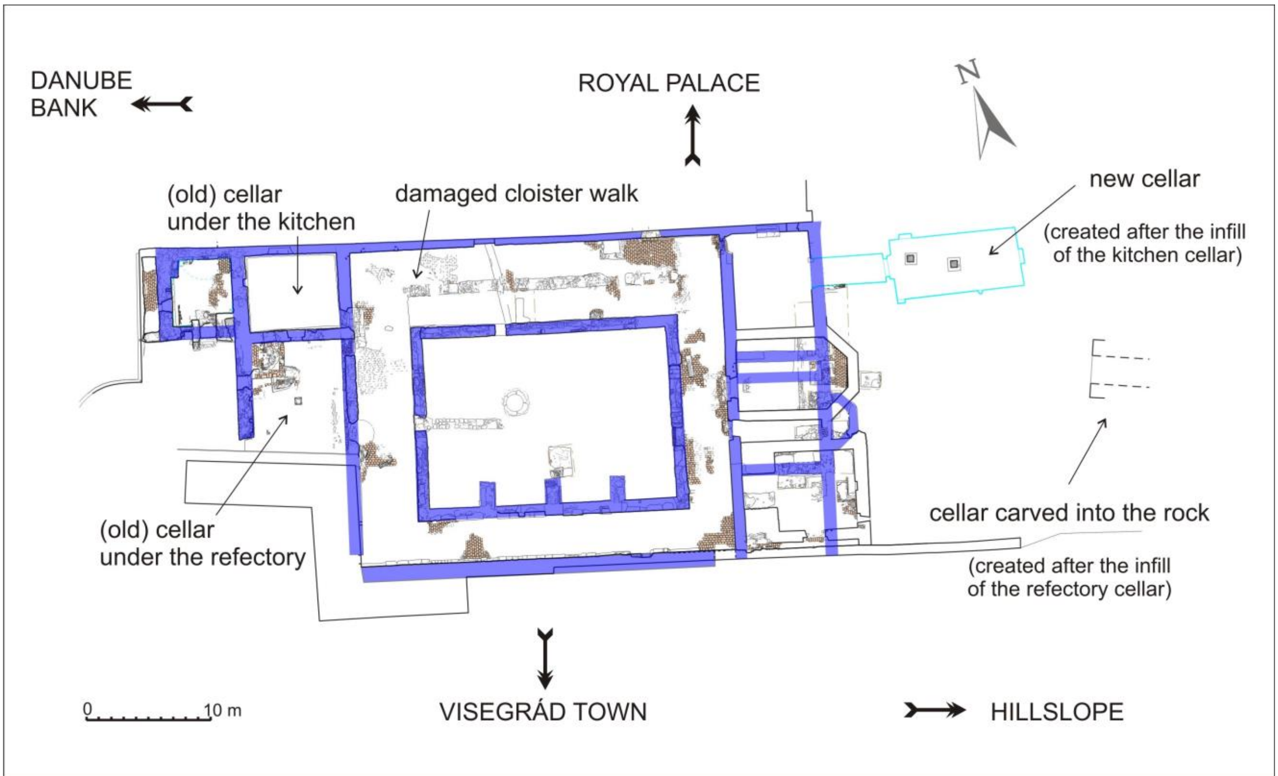

Fig. 3 Layout of the excavated early 15th-century Franciscan friary in Visegrád

mer cellar under the refectory close to the Danube (western side of the friary), and the establishment of the other, new cellar far from the Danube (eastern side of the friary), carved into the rock of the hill presumably occurred in the same time. Based on these features, the location of the friary, the stratigraphy and morphological conditions of the area, the excavators presume that this major damage, occurred some time between 1514 and 1540, had strong connections with Danube floods happened around the same time, and also with the generally rising trend of Danube water levels.

Compared to the palace area and the urban settlement centre, the Franciscan friary was more seriously affected by these floods. Similar situation was observed during the 2002, 2006 and 2013 flood events (e.g. water was standing in the former, medieval cellars). This observation offers an explanation for the major damages of the northern cloister walk, while no similar damages were detected during floods in the palace area.

In case of the Franciscan friary in Visegrád three conclusions were drawn on the basis of the excavated features. The building process of the friary in the 1420s was preceded by a significant ground-level rise compared to the previous ground level of the 14th-century buildings. This ground-level rise was probably necessary because of the long-term rise in Danube (flood) water levels (as described also by Héjj for other parts of the town). The great flood events of the 1500s and/or the floods of the entire late 15th–early 16th-century flood peak as well as the above described long-term water-level rise had a clear impact on the early 16th-century re-building processes in the form of a significant rise of ground level, and also with the infill of the cellars located close to the Danube (Kiss and Laszlovszky, 2013).

Between 1514 and 1540 at least one or more destructive flood events had to have strong impacts in the area which caused considerable damage in the buildings, so that a major reparation had to be carried out. Concerning these decades, as shown in *Fig. 1*, the great 1515 flood event or the series of flood events reported prior to 1523 (see later the case of Margit Island) or the floods around 1529-1531 as well as in the mid-1530s could be responsible for these damages (see *Fig. 1*). All these floods or flood series, otherwise, were also reported either on the Austrian or the Bavarian sections of the Danube (more information: Kiss and Laszlovszky, 2013).

Increasing 14th-16th-century groundwater levels near the Danube? The example of Vác

Related to the late medieval–early modern, long-term Danube water-level rise, interesting observations were recently published concerning the medieval-early modern Vác (Mészáros and Serlegi, 2011). The authors found it possible that already in the 15th century a cellar had to be filled up (by litter) because of the generally rising groundwater-level conditions, which strongly depended on the Danube water levels. In general, a significant increase of groundwater level was detected between the 13th–14th- and the 16th-century situation. Similarly, the bottom of the well, constructed in the second half of the 16th century, was 1.7 m higher than the bottom of the wells constructed one-two centuries before. It is really interesting, however, that the 17th-century well had a bottom ca. 60 cm lower then the late 16th-century one. Same observations were made in case of other, 17th–18th-century wells, which were all somewhat deeper than the late 16th-century one. The bottom of the 19th-century well was 2 m deeper than the 14th–15th-century ones. Nevertheless, in this later, 19th-century case the groundwater level could be already influenced by the increased water take-off due to strong population growth.

Thus, for the 16th-century, with no elevation change of the surface (ground) level, the authors reconstructed rather high average groundwater levels. Based on the observations carried out in wells and cellars, the average groundwater level of the (late) 16th century was much higher than in the Middle Ages, or in other parts of the early modern times, but also much higher than in the 19th century. In general, similarly to the observations of Miklós Héjj (1988) concerning the rising water-level conditions of the Danube between the 14th and 16th centuries, a significant groundwater-level rise, presumably influenced by the water levels of the Danube, was reconstructed by Mészáros and Serlegi (2011) concerning the same period in Vác.

It is also important to note that the highest water level was reconstructed for the second half of the 16th century, and already lower water levels were detected in the 17th century. The second half of the 16th century was also a very important period on the Danube (and also on most of its tributaries), especially because of the unusually great number of extraordinary (summer) floods. Significant floods especially were detected in the late 1560s–early 1570s when almost in each year there were great and extraordinary flood events (see *Fig. 1*); but already the 1550s as well as the 1580s-1590s are important flood decades (Kiss, 2012b; Kiss and Laszlovszky, 2013; for great floods of the Austrian sections: Rohr, 2007; Sonnlechner et al., 2013; for the Danube at Ulm: Glaser, 2008; for major Bavarian tributaries: Böhm and Wetzel, 2006). It could easily happen that these flood events were combined with generally higher water-level conditions on the long-term, detected in the archaeological evidence (e.g. at Vác).

Flood risk, early 16th-century building process and holy bones: the Margit Island (Budapest)

On the Margit Island (a Danube island located between Buda and Pest) before the Turkish occupation of the Buda area in 1541, the last great building process on the Dominican nunnery complex and the royal manor started in the late 15th century, continued in the early 16th century. The early 16th-century re-building of the royal manor, located nearby the monastic church, had some elements which, according to the excavating archaeologist, served the purposes of flood defence: the floor level was raised with 40-60 cm, and buildings were surrounded by large stone sheets in the open spaces (Irásné, 2004b). According to Feuerné (1971), another archaeologist working before in the same excavation area, the tomb of Margit could be emptied years before 1529, because the nuns – referring to the devastations of floods – had previously removed the holy remains. Although without any further reference on the source, the author presumably referred to the charter issued in 1523 which contained the permission for changing the location of Margit's bones due to its flood-endangered place (HNA DL 25312; for a recent overview, see Vadas, 2013). An earlier building process was also detected on the mid 13th-century monastic sites, which started around 1381 and was still going on in 1409 (Feuerné, 1971).

Thus, in case of the Dominican monastery at least two flood-risk periods can be identified: one occurred in the early 16^{th} century (or short before), and the other, occurred in and (short) before 1523. Concerning the available documentary evidence, the earlier, archaeological evidence can be easily connected to the great flood peak of the (late 15^{th}–) early 16th century. Nevertheless, the second (documentary) case referring to significant floods prior to 1523, with currently no available single flood references, might need more explanation. Although in the Carpathian Basin (apart from the great flood in 1515) at the moment no contemporary reference on Danube floods is available, important Danube floods were reported concerning the Austrian and Bavarian sections in 1520 (Melk; see: Pertz, 1851), 1522 and 1524 (Regensburg; see: Heigel, 1878). Moreover, the Traun river, which is a good indicator of the conditions in the Eastern Alpine catchment of the Danube, had a significant flood period at that time: damaging flood events (sometimes three in a year) occurred in each year between 1519 and 1522 (Rohr, 2006).

MAIN FLOOD PEAKS DETECTED IN THE 14^{th}-16^{th} CENTURY: DISCUSSION

As for a conclusion and discussion of results, it is useful to have an overview of the evidence listed above according to main reference periods (see *Fig. 4*).

The 14^{th}-15^{th} centuries

In case of the Visegrád and Vác archaeological investigations, either based on settlement change observations or well depth measurements, a significant increase of water-levels, under the presumable direct influence of the Danube, was suggested concerning the (14^{th}–)15^{th} and 16^{th} centuries (Héjj, 1988; Mészáros, 2006; Mészáros and Serlegi, 2011). In the second half of the 14^{th} century, after the destruction of wooden buildings, the ground-level rise of the yards (accompanied by change to a brick based building structure) was observed in Šamorín (Urminský, 2005). A significant ground-level rise was also detected at the building process of the Franciscan friary in the 1420s, compared to the earlier, 14^{th}-century level of the settlement. In connection to this question, it might be also interesting to see whether or not any change could be detected at such a flood-sensitive location as the Margit Island during the late 14^{th} and early 15^{th} century building process.

As for the Danube flood information preserved in documentary evidence, both in Austria and Hungary a clear increase was detected in the reported number of large flood events in the first decades of the 15^{th} century. Although more Danube flood references could be found in the Carpathian Basin in the 15^{th} than in the 14^{th} centuries, and this is especially true for the first and last decades of the 15th century, this difference can be also caused by the differences in documentation between the two centuries. More floods (also Danube floods) are mentioned in the Carpathian Basin from the end of the 14^{th} century, but especially in the first decades of the 15th century, when long-term problems were as well documented (see *Fig. 1*; and Kiss 2011, 2012a). The increased number of large flood events on the Danube in the early 15^{th} century is also clearly detectable in the contemporary Austrian documentation (Rohr, 2007). Whereas a somewhat increased flood activity can be witnessed in the Upper-Danube flood reconstruction referring to Ulm, not much sign of a high flood frequency period is yet found around the turn of the

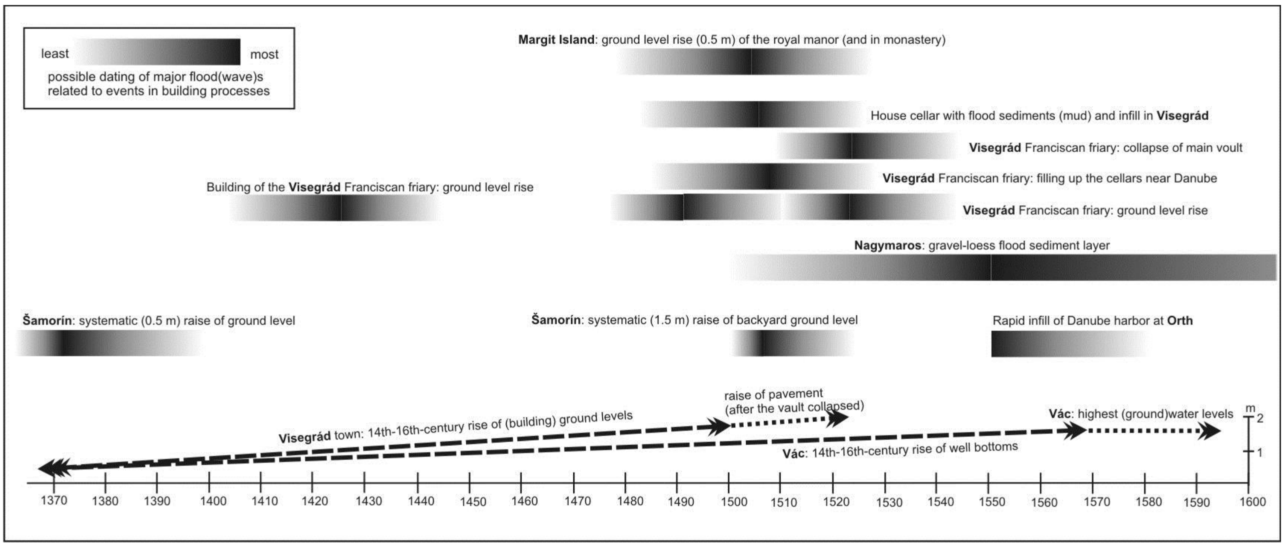

Fig. 4 An overview of 14^{th}–16^{th}-century Danube flood related archaeological-sedimentary evidence in the West and Central Carpathian Basin

14^{th}–15^{th} centuries or in the early 15^{th} century (compared to, for example, the extreme flood peaks of the late 17^{th} or the mid 18^{th} centuries). A moderate increase in recorded flood events are presented concerning the second half of the 15^{th} century (for the Danube flood reconstruction at Ulm, see Glaser, 2008).

Thus, some of the archaeological evidence (e.g. Vác and Visegrád) suggests long-term rising water-level conditions of the Danube between the 14^{th}-16^{th} centuries. Moreover, some late 14^{th}- or early 15^{th}-century changes in building processes (e.g. ground-level rise: Visegrád, Šamorín) were also detected. In case of Visegrad this was explained by the generally rising (flood) water levels, but these processes might be also connected to the flood peak at the end of the 14^{th}, but especially in the first decades of the 15^{th} century. Therefore, further investigations are needed to identify the nature of this relationship. More evidence is available from the late 15^{th} century when new building processes started in a number of places along the Danube: a ground-level rise was clearly detected, for example, in case of the new building process of the Franciscan friary in Visegrád. Since most of related archaeological evidence were dated to the late 15^{th}–early 16^{th} centuries without further specification on timing, the late 15^{th} century is discussed bellow together with the early 16^{th} century.

The (late 15th and the) 16th centuries

The relationship is more straight-forward and easily detectable concerning the late 15^{th} and 16^{th} centuries: the much larger number of archaeological and sedimentary evidence culminate around the late 15^{th}–early 16^{th} century and mid 16^{th} century, as well as around the second half of the 16^{th} century. In all three cases already a significant number of documentary evidence is available for studying the possible relationship between flood peaks, long-term water-level changes and some of the available archaeological and sedimentary evidence.

Considering long-term groundwater-level changes in relation with the Danube, in case of Vác investigations showed clear difference between the late medieval situation of lower water levels, and the highest, late 16^{th}-century water levels. Compared to the late 16^{th}-century high water levels detected in wells, the 17^{th}-century again showed a contrast with its lower water-level conditions. The flood (or floods), marked by a gravel-loess layer in Nagymaros, could have occurred any time between the late 15^{th} and the 17^{th} centuries. While in these two cases no exact dates or decades of flood processes can be detected (except for the very high late 16^{th}-century water levels), in other cases the changes can be more clearly connected to certain decades, and therefore, it is possible to discuss them in time division.

1) The late 15th and early 16th centuries:

As we could see, a significant rise of yard levels (1.5 m) was reconstructed in Šamorín, while an important (over half meter) ground-level rise could be also detected in the early 16^{th} century, both in case of the Visegrád friary and the Dominican nunnery at the Margit Island. The influence of great flood events is probably the most clearly detected in the Visegrád cases. Another clear consequence was the infill of cellars (due to repeated flooding), detected both in Visegrád town centre and in case of the Franciscan friary.

In documentary evidence, primarily based on the information related to Bratislava, a significant flood peak was reconstructed concerning the late 15^{th} and early 16^{th} centuries: starting with 1478, the 1480s, 1490s and 1500s were especially rich in destructive flood events. Moreover, the extraordinary flood events occurred on the Austrian sections of the Danube in 1501 ("millennium flood"), 1503 and also in 1508, which great flood waves presumably also appeared on the Carpathian Basin sections. Observations concerning the early 16^{th}-century significant ground level rise as well as the infill of cellars due to flood danger show parallels to what happened after 1501 along the Austrian sections of the Danube (see Rohr 2005): apart from rising ground levels concerning new building processes, in Engelhartzell after the 1501 flood the toll house had no windows at the ground floor.

Great flood(s) after the early 1510s caused significant damages in the Franciscan friary of Visegrád: based on documentary information, in this case either the great 1515 flood event, the flood series prior to 1523 or the (great) floods around 1530 (1529, 1530, 1531) as well as in the mid 1530s (1535, 1537) might be responsible for the major damage.

2) Mid-16th century and the second half of the 16th century:

As for the upper sections of the Danube, at Orth concerning the rapid in-fill process of a harbour, high intensity sedimentation process (which could as well be connected to a higher number of more intense flood events) was detected around or short after 1550. This event might be a process parallel to the great 1548 flood event or the floods of the 1550s.

In Vác the highest water levels in wells were detected in the second half of the 16^{th} century (Mészáros and Serlegi, 2011); the Nagymaros gravel-loess layer was also dated by the same authors for the mid or late 16^{th} century. Parallel investigations suggest the intensification of fluvio-morphological processes (increased channelling activity and sedimentation) around the same time on the Danube in the Bratislava and Žitný ostrov area as well as at the lower sections of the River Morava.

These processes correspond to the great flood peak, especially documented concerning the second half of the 16^{th} century, culminating around the late 1560s and early (mid) 1570s, characterised by great material damages and long-lasting inundations (e.g. in the Bratislava and Žitný ostrov area in 1574).

CONCLUSION AND OUTLOOK

In a growing number of cases, results of archaeological and sedimentary investigations can be directly or indirectly connected to large Danube flood events, series of floods events and/or general, long-term changes in water-level conditions. The processes detected in archaeological evidence are partly long-term changes: a general rise of the Danube (flood) water levels were detected concerning the 14^{th}-16^{th} centuries. This water-level might have reached its peak in the second half of the 16^{th} century.

Medium and short term evidence mainly corresponds to the main flood peaks or even to single catastrophic flood events. Such processes may be identified in archaeological evidence concerning the second half of the 14^{th}, early 15^{th} centuries; while most of the cases listed above were connected to the flood peak (and/or generally increasing water-level conditions) of the late 15^{th} and early 16^{th} centuries. In other cases connections between sedimentary/archaeological evidence and the mid- and late 16^{th}-century high flood-frequency period were presumed.

Documentary evidence referring to the same period suggests that higher flood frequency and intensity periods occurred in the early and mid 16^{th} century; a probably more prolonged one took place in the second half of the 16^{th} century, with a peak in the late 1560s-early 1570s and maybe with another at the end of the 16^{th} century. Earlier flood peaks in documentary evidence were detected on the Danube at the turn of the 14^{th}-15^{th} centuries and in the last decades of the 15^{th} century, continuing in the early 16^{th} century.

Comparing the above-mentioned results with the only available, systematic long-term Upper-Danube flood reconstruction (see Glaser, 2008: for Ulm, Germany), some clear similarities and differences can be recognised: based on the available documentary evidence, in Ulm a (smaller) flood peak was reconstructed for the second half of the 14^{th} century, and a moderate increase in the second half of the 15^{th} century. The real increase in flood frequency can be observed on the Ulm series only after the first decades of the 16^{th} century, which tendency more intensively continues from the mid 16^{th} century onwards.

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