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Destruction of the royal town at Visegrád, Hungary – historical evidence and archeoseismology of the 1541 AD earthquake at the proposed Danube dam site

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Abstract

The Danube Bend is the site of the proposed Nagymaros dam, part of the Gabčikovo-Nagymaros hydropower complex in Slovakia and Hungary. The dam was designed in the 1970s to resist intensity VI seismic events. We present historical and archaeological evidence for an intensity IX earthquake on 21 August 1541, which destroyed buildings of the royal town of Visegrád. Evidence includes vertical fissures cutting through the 30 m high, 13th century donjon Salamon Tower, built on hard rock. Some parts of the adjacent 15th century Franciscan friary, built on the alluvial plain, collapsed due to liquefaction of the subsoil. The date of a potentially responsible earthquake on 21 August 1541 was recorded in a sermon of the eyewitness Lutheran minister Péter Bornemisza, living at Pest-Buda, 35 km away. Taken by the Ottoman army in 1544, the royal town and the fortress lost strategic importance, never to be rebuilt. Photographs and drawings of the donjon made three centuries later faithfully reflect the status of 16th century seismic damage, corroborated by modern archaeological excavations in the ecclesiastic complex.

Introduction

The Danube Bend in Hungary is the site where the second largest river in Europe crosses the Transdaubian Midmountains, actively carving a 200 m deep gorge in bedrock (Ruszkiczay-Rüdiger *et al.*, 2005, Karátson *et al.*, 2006). The U-shaped turn of the river might reflect as yet unknown tectonic processes (Fig. 1). The site has been favoured for damming the river for almost a century. This came close to true when Czechoslovakia and Hungary joined forces to build the Gabčikovo-Nagymaros hydropower complex in the 1970s (Salewicz, 1991; Fürst, 2006). Seismicity of the region was considered minimal; there were neither recent nor historical earthquakes known nearby the planned installations (Réthly, 1952; Zsíros *et al.*, 1988). The proposed dam at Nagymaros within the Bend was designed to resist earthquake shaking of intensity VI on the MSK-64 scale (Mistéth, 1987). Engineering geological studies in the foundation trenches did not find any seismic indicator (Gálos *et al.*, 1988). Later, however, doubts were raised about seismic safety (Cserepes *et al.*, 1989). A suggestion that design intensity should be IX was rejected by structural engineers based on apparent millennial integrity of medieval fortifications nearby (Mistéth,1994). Ultimately, as a result of the political changes in 1989, the Hungarian government withdrew from the project, inviting international arbitration to ease tensions between the two states. The issue of whether Hungary should or should not build the Nagymaros dam is still unsettled today (Fuyane and Madai, 2001). In this paper we present historical, archaeological data, and archaeoseismological evidence indicating severe destruction of medieval buildings by an earthquake near the proposed dam.

Methods

Two buildings were studied in detail: Salamon Tower and the Franciscan friary next to the royal palace. Historical note on other monasteries and palaces within town were also taken into account. Stratigraphic analyis of excavated soil layers and their relationship to foundations of medieval buildings were used to interpret different architectural elements of various building complexes. Surviving wall structures of medieval buildings were interpreted with building archeological techniques and the results were incorporated into architectural-historical conclusions. Various damage features within the buildings were identified, measured and described, based on careful field work. Observed features were documented by drawings and photographs, both by single shots and structure-from-motion technique (Forlin *et al.*, 2017). Dimensions, orientation and tilt angles were measured using laser range finder, measuring tape, and a clinometer. A novel method was used to characterize featureless deformed floors (Kázmér and Al-Tawalbeh, 2021). The subsided surface was divided by grid points in a 10 cm by 10 cm network. A laser device (Bosch Universal Level 2) and a measuring pole with cm subdivision was used to measure elevation differences. TIN interpolation by ArcGis 10.4 yielded a 3D model, labelled by the Corel X5 graphic software. The ESI-2007 Environmental Seismicity Intensity scale (Michetti *et al.*, 2007) was used to determine the intensity of the seismic event.

Visegrád in the Danube Bend

The twin settlements of Visegrád and Nagymaros are facing each other about 600 m apart on the right and left bank of the Danube river, respectively (Fig. 1). Visegrád had been one of the royal residences of the Kingdom of Hungary between the 13th and the 16th centuries, and the capital of the country in the 14th century, while Nagymaros was a prosperous trading settlement in the Middle Ages. From the middle of the 16th century, upon occupation of much of Hungary by the Ottoman empire, the town declined, never regaining its previous importance. Construction ceased, buildings were abandoned, robbed for stone, and finally covered by landslides (Iván, 2004).

Both Visegrád and Nagymaros were built on the lowest, Pleistocene terrace of the Danube, extending onto the adjacent mountain apron (Pécsi, 1959). We studied the very few surviving medieval buildings in Visegrád, namely Salamon Tower, a 13th century donjon, the royal palace complex and the adjacent Franciscan friary (Kázmér *et al.*, 2019) to find evidence for any past seismic events.

Salamon Tower

Salamon Tower, built on and made of Miocene andesite pyroclastics (Török, 2008) stands about 35 m above the river on a steep hillside in the northern outskirts of Visegrád town. Its plan forms an elongated hexagon, 30 m long in north-south direction and 17 m wide. Elevation is preserved up to 30 m height (Fig. 2). The tower was the centre of the lower castle of the Visegrád fortification system, controlling river and road traffic of the Danube Bend in tandem with the upper fortress on the hilltop 200 m above. Salamon Tower was built by King Béla IV in the late 13th century for a royal residence. It underwent architectural changes in its internal structures in the 14th century. Later it was converted for purely military purposes.

The tower had five floors. The walls are uniformly 3.5 m thick, except in the southern and northern corners, where they are 8 m thick. There are windows surrounded by carved frames both on the eastern and western sides at each level. A staircase, embedded within the 8 m thick wall of the southern corner, provided access to the floors.There is a huge collapse scar where the southern corner had been, revealing five floors of open space within the building. Vertical fractures transect each standing wall. The destruction and the damage of this corner of the tower are connected to a military siege of the lower castle complex.

The siege in 1540 made the southern corner collapse due to four days of cannonfire (left side in Fig. 2). The lower castle complex and the tower, occupied by the Ottoman army four years later, lost its strategic importance, never to be rebuilt to its original purpose. Still remembered as a royal residence in the 19th century, it has been subject to various restoration attempts, some of them applying stone materials in the 19th century, as well as concrete on the damaged and destroyed facade parts, a widespread restoration method in the 1970s. Plastering and inserting new stones in the facade effectively covered all damage features (Bozóki, 2005, 2014), but they can be studied on the architectural surveys and documentation of this historical monument created before the restoration projects. Nineteenth-century images (drawings and photograps) reveal the condition of the buildings right before 1544, the year of Ottoman conquest (Figs 2-3). These allow archaeoseismological study to recognize damage features and assess them by comparison to published images and to own photographs in the Archaeoseismological Database (Kázmér and Moro, 2021).

Besides the obvious collapsed southern corner, victim to the 1540 siege (Iván, 2004), there are further features of destruction, which cannot be related to cannonfire. The western facade bears a conspicuous vertical fracture, connecting the weak zone of windows, across all five floors (Fig. 3). Earthquake-hit towers, like donjons or church towers, often bear similar fractures, located halfway between opposing walls. The fractured towers of the *kasbah* of Sousse, Tunisia (Bahrouni et al., 2020, their fig 4.2), of St. Peter's church, Broadstairs, England (Musson, 2007, his fig. 10), and of San Agustín church, Manila, Philippines (Saita *et al*. 2004, their fig. 5) are good examples. Often one half of the tower collapsed, while the other half remained standing (e.g. the clock tower in Finale Emilia in Italy; Acito *et al*., 2014). While the collapsed southern corner is historically proven to be victim of cannonfire on 12 October 1540, all other fractures developed in places protected from artillery. We suggest that these were formed by seismic shaking.

Franciscan friary

There are extensive excavated ruins of a Franciscan friary adjacent to the royal palace in Visegrád (Buzás *et al*., 1995). It was founded by King Sigismund in 1424-1425, expressing both financial and spiritual closeness between the crown and the 'gown' (the religous order), as Laszlovszky (2009) put it. An east-west-oriented Gothic church, dedicated to Virgin Mary and the attached, rectangular cloister building for the observant Franciscan order were built on the lowest terrace of the river Danube. King Mathias provided funds for renovation and enlargement in 1470-1480. The northern wing (cloister walk) of the rectangular cloister, being wider than the rest, was constructed with a row of red marble columns to support the double row of vaults erected during the time of King Vladislav II Jagello (ruled 1490-1516). There were friars' rooms above the vaulted corridors. There are no upright walls higher than 1.5 m preserved in the cloister, and therefore we studied the floor for deformation (Fig. 4).

Subsoil

The cloister was built right next to the hillslope in the east. Neither sand nor gravel of the former riverbed was found during excavations (Fig. 5, Table 1). The 5 m deep well in the courtyard (cloister garth) yielded ample amount of water, which had to be pumped throughout the excavations. Clearly, the soil layers close to the surface in the cloister garth are landfill down to

1.8 m depth, as has been documented in various cross sections of archaeological sondages excavated in this part of the building complex. The main walls of the cloister stand on autochthonous clay, providing a solid foundation to the building.

Damage in the cloister part of the Franciscan friary

The cloister walk (a covered corridor with four wings sorrounding the rectangular cloister garth) was floored with bricks embedded in mortar. The floor, originally horizontal and flat, displays an undulating surface today (Fig. 6). Various parts of the floor are 10 to 80 cm below the original level, marked by the top of the foundation walls (Fig. 4, Site 5). There is a distinct depression in the northwestern corner, ~40 m^2 in area, up to 80 cm deep (Fig. 4, Site 6-7, and Fig. 7). A 3D model was created to show the shape of the otherwise featureless floor. The calculated volume of the depression is 14 m^3 (Fig. 8).

There is a stair of two steps on the western side of the depression (Fig. 4, Site 8 and Fig 9). Both floor and stairs are tilted to the north. Original level is marked on Fig. 9. The northern termination of the stairs is 70 cm deeper than the original location. The northern wall of the cloister contains several holes (Fig 3, Site 9, and Fig. 10); these probably held beams of a temporary wooden floor above the depression.

The foundation wall along the centre of the northern sector of the cloister – which supported the red marble colonnade – displays uneven settlement of about 50 cm (Fig. 7).

Discussion

Flood versus earthquake – mechanism of damage

Archaeologists faithfully recorded destruction features (Buzás *et al*., 1995; Halász and Mordovin, 2002; Laszlovszky és Romhányi, 2003) during excavations in the late 1990s, attributing those to warfare, abandonment, and stone robbing. Later Kiss and Laszlovszky (2013) suggested that increased level of Danube floods in the early 16th century caused structural damage to the cloister. These floods are well documented in historical records, and also at some archaeological sites. However, Danube floods, usually lasting from a few days to a few weeks only, occur in modern times, too. These damage furniture in flooded houses, may damage plaster on walls, but do not cause damage to stone or brick masonry. Adobe buildings, however, collapse instantly upon inundation. The Franciscan friary was a well-constructed stone masonry building; it certainly did not collapse from flood. Frequent floods inundated the Dominican nunnery on Margaret Island near Buda, about 35 km downriver. Narrative sources from the 13th century onwards report floods influencing the daily life of the inhabitants there, never mentioning any major structural damage to the buildings (Vadas, 2013). However, floor levels were often raised to minimize the disturbing effects of frequent floods, as documented in various building on Margaret Island.

Liquefaction

We suggest that the collapse of the northern cloister walk of the Franciscan friary was due to significant deformation caused by liquefaction of the subsoil. The resulting uneven settlement produced subsidence of buildings or their parts. Short-lived fountains and sand volcanoes could develop on the surface, removing 14 m^3 of sediment from below the floor (Fig. 7) (Bray and Dashti, 2014; Győri, 2005).

The major walls of the cloister are standing on solid, grey clay. The soil below the brick pavement of the cloister is loose landfill, partly excavated from foundation trenches. It contains construction debris and archaeological objects (Fig 5, Table 1). The foundation wall under the colonnade in the middle of the northern cloister walk was also laid down on this landfill. The brick pavement all over the cloister walk is underlain by landfill, too. This is why both the foundation of the columns subsided severely and the pavement subsided in all wings of the cloister walk. Even in modern times the subsoil is saturated by water; inflowing water was pumped from the well during excavation.

A spectacular depression was formed in the northwestern corner of the cloister: 0.8 m subsidence of the floor was caused by escape of 14 m^3 subsoil from below the floor. Only liquefaction-induced escape of sediment-laden, overpressured water can remove such large amount of material. The escape could have been laterally directed into the adjacent cellar to the west; alternatively, it could have been filtered through tiny fissures in the brick floor, and subsequently removed during cleanup after the catastrophe.

Another possibility to explain the reported damage to the friary cloister, also related to the liquefaction event, is land slumping or lateral spreading induced by the earthquake shaking. A significant part of the described damage took place in the part of the cloister closest to the river, i.e. on the downhill side of the bank upon which the cloister was built (Fig. 4). Strong earthquake shaking could have caused some minor slumping towards the river of the loose sediments at the site, moving some earth material away from beneath the cloister. Perhaps some of that material might have moved into the cellars, but it is also possible that a part of the hillside that included the cloister simply moved downhill toward the river. An objection can be raised against this idea: the friary is 180 m away from the riverbank. The remaining foundation walls are intact, did not suffer any lateral deformation. Further planned excavations might clarify this issue.

Floor depressions in the cloister of the friary are not unique to Visegrád. Worlwide examples of uneven settlement with depressions of similar dimensions (diameter and depth) associated with strong earthquake shaking and liquefaction were described, among others, for Roman mosaics of Monastir, Tunisia (Bahrouni et al. 2014), the Byzantine cathedral in Corinth, Greece (Apostolopoulos *et al*., 2015; Minos-Minopoulos *et al*., 2015), in the city of Ferrara, Italy (Caputo *et al*., 2016), and in Byzantine Gadara in Umm-Qais, Jordan (Fandi, 2018).

Which earthquake?

We are looking for an earthquake which might be responsible for the damage observed both on the Franciscan friary and on the Salamon Tower. One must be aware that 90% of earthquakes during the last millennium in the Carpathian-Pannonian region went unrecorded; therefore there is not much chance to find the culprit (Kázmér and Győri, 2020).

When did the earthquake happen? There is no historical record preserved about the destruction at Visegrád. We set up a detailed construction and restoration history of the Franciscan friary and correlated it with the very few historical documents to bracket an interval in which the catastrophic earthquake occurred (Table 2).

When did this thorough destruction happen? Destruction certainly happened after the Franciscan convent met in 1513, probably after 1535, when still eight brethren inhabited the rooms above the northern cloister walk, and possibly after 1539, when the monastery still had a full hierarchy of inhabitants (name of the guardian is known), and when King John Zápolya had the royal palace next door repaired in 1539. The *terminus ante quem* is the Turkish occupation of nearby Esztergom in 1543 and of Visegrád proper in 1544.

Record of an earthquake on 21 August 1541

Historical earthquake records are mostly missing from 16th century Hungary (Kázmér and Győri, 2020). However, there is an interesting historical record available for the period between the Austrian siege of 12 October 1540 and the Ottoman occupation of Visegrád in 1544 (Varga, 2017).

Péter Bornemisza (1536-1584), an important Lutheran minister and writer, wrote in one of his sermons in Hungarian:

> *Hatod Ielről monda: Es leßnec Főld indulasoc bizonyos helyeken. Ez ackoris meg lett midőn Chri-/stus wrunc Lelket ki boczatta, es halottaibol fel tamadot, Es az vtannis. Mi időnkbennis Buda veßedel-/me előtt az Nap annira el veztette fenyet, hogy deelbe az Czillagokat latnac, es olly föld indulas lett, hogy az polczrol az fazokac le hulnanac, es az tornyokis romlanac, ottis Budan és Pesten az en házamba.* (Bornemisza, 1584, p. DCCVI).

In English:

> *On the sixth sign he said: there will be earthquakes at certain places. This happened when our Lord Christ died and resurrected. Then, in our times, before the peril of Buda the sun lost its light so much that at noon one saw the stars, and an earthquake happened, pots fell from shelves, and towers damaged, in Buda and in Pest in my house.*

This paragraph refers to the Book of Revelations in the Bible, verse 11,13: „*And that same hour there was a great earthquake, and a tenth part of the city fell”*. The peril of Buda means the arrival of the Ottoman army to occupy the castle on 29 August 1541. The loss of sunlight was due to a partial solar eclipse (Kaposvári, 2006) on 21 August 1541. Bornemisza is considered a reliable source, even though his sermon was put on paper decades after the event (Péter, 1996). The child Bornemisza, living in Pest (now part of Budapest) at the age of six, could have remembered these two frightening events, and family stories certainly made him remember that there was an earthquake and an eclipse on the very same day. A record, when a historical date is confirmed by an astronomical date, can be considered reliable (Guidoboni and Ebel, 2009). Environmental historians dealing with historical records on catastrophic natural events (earthquakes, floods, invasion of locusts) have recognized characteristic features of such texts and the historical value of such reports have also been discussed. While catastrophic events mentioned in the context of divine interventions or as signs for the activity of supernatural powers are treated as less reliable or problematic, reports depicting actual events with minor interesting details are often seen as confirming evidence for the historical value of the given text. Furthermore, catastrophes recorded soon after the actual event or under special circumstances are usually treated as important evidence, while stories described decades later are often less useful. In an interesting and complex way, the above quoted paragraph written by Bornemisza shows various characteristic features of such texts. Although the earthquake and solar eclipse are discussed in a religious context, with the reference to Jesus Christ, the actual event with its chronology is placed in the context of a well known historical fact. The conquest and occupation of Buda and Pest by the Ottoman army was not only an important turning point in the history of Hungary, but also a dramatic event in the personal life of Bornemisza. He grew up in Pest, and at the age of six he has lost his parents during the events connected to the occupation of these towns. He had to leave the place and the rest of his childhood was connected to other families in other parts of the country.Therefore, we can speculate that events occuring right before this dramatic change of his personal life survived as vivid memories for him decades later. This is also corroborated by the fact that the date of the solar eclipse can be confirmed by astronomical calculations, and it was definitely before the Ottoman occupation. Furthermore, the minor details recorded in the context of the earthquake (falling pots, damaged towers) are typical features of reliable historical sources on catastrophic events. These details are also coherent with the memory of a six year old child, and they are based on eyewitness observations. Thus, we can firmly conclude that Bornemisza's report is a good and relevant source for a strong earthquake for a period not much before the Ottoman occupation of Buda.

The Hungarian Earthquake Catalogue lists this event with an intensity of VI and magnitude 4.1 (Varga, 2017). This earthquake, as felt in Pest, might have had its epicentre elsewhere, closer to Visegrád than to Pest.

Total destruction?

How much destruction was inflicted by the earthquake on the royal town of Visegrád? The most solid building, Salamon Tower, boasting 3.5 to 8 m thick walls – already partially damaged by cannonfire – had fractures in protected walls from top to bottom. Some vaults of the Franciscan friary collapsed, and the cloister walkway floor suffered severe differential settlement due to liquefaction of the subsoil. This collapse and liquefaction have occurred in those parts of the building complex where vaults and floors were constructed on mixed infills. However, it is not only architectural observation and archaeological evidence which indicate significant damage, as visitors some time later described their experience about Visegrád.

David Ungnad was envoy of the Austrian emperor. On an official trip from Vienna in 1572, he stopped at Visegrád en route to the Sublime Porte in Constantinople. The chronicler in his entourage took notes of the decrepit condition of the royal castle and the friary (Ferus, 2007:99). Another chronicler a few years later described the town of Visegrád as ruined (Gerlach, 1674:9). Reinhard Lubenau, a German traveller from Königsberg, accompanied the Austrian ambassador travelling from Vienna via the Danube to Constantinople. The team visited Visegrád in 1587 and described the sad condition of the buildings there:

„...uber der Thona zur rechten Handt leidt eine gahr schone Festung aus einem hohen Berge, zu welcher wir hinuber gefahren, dselbe zu besichtigen; unter dem Berge wahren ein Hauffen // zerstöreter palatia, groser Herren Hauser, Kirchen und Klöster, auch ein koniglich palatium, Lusthaus und Gartten auch grose Mauren und allerlei Gebeude, elche alle zerstöret un sol Keiser Sigismundus dies palatium haben angefangen zu bauen, und von Matha Corvino volendet worden, aber von den Turcken zerstöret..” (Sahm, 1912:76).

In English:

„...over the Danube on the right hand there is a nice fortress on a high mountain, where we went to visit; under the hill there are houses, broken palaces, large noble houses, churches and monasteries, also a royal palace, an event house, and garden and large walls and other buildings, all of them destroyed. Emperor Sigismund started to build this palace, Mathias Corvinus finished, but the Turks destroyed...”

Lubenau attributed all damage to the Turkish army, as heard from his guides. However, neither the Austrian army in 1540 nor the Ottoman army in 1543-44 had any reason to attack monasteries and other houses in town. Their aim was to occupy military installations; the lower castle, including Salamon Tower near the river, and the upper castle on the hilltop. We suggest that the severe damage to the town buildings was caused by the same earthquake which fractured Salamon Tower and destroyed much of the Franciscan monastery.

Intensity

There are only low upright walls preserved in the Franciscan friary. Therefore, the Earthquake Archaeology Effects scale (Rodriguez-Pascua *et al*., 2013) cannot be applied here. The Environmental Intensity Scale (ESI07) lists: „liquefaction frequent, sand boils up to 3 m diameter, settlement/subsidence of more than 30 cm but less than 1 m”. The 6 m diameter depression in the cloister, 0.8 m deep, fits in this category, indicating intensity IX or higher (Michetti *et al*., 2007). This high intensity earthquake in Visegrád could have been felt in Pest by Bornemisza as intensity VI event (Varga, 2017) (Fig. 11).

These values are correlated with the previously used MSK-64 scale (Musson *et al*., 2010), used in designing the Nagymaros dam (Mistéth 1987, 1994). One can see that design itensity VI, applied for the dam in the 1970s, has been underestimated. Intensity IX – as suggested in the 1980s by experts of the Geophysical Institute but rejected by Mistéth (1994) – is a more realistic value. Any further seismic design for critical facilities in the region of Visegrád need to consider this event.

Causative fault

Extensive shallow seismic profiling along the Danube between Esztergom and Budapest revealed large number of potentially active, mostly strike-slip faults across the riverbed. Their number is several times higher than those known from outcrops on land (Oláh *et al*., 2014). We can neither corroborate nor exclude that any of these were active in historical times. There was no systematic survey for surface ruptures. Historical map studies on the changing Danube riverbed (migrating sand banks, see e.g. Székely *et al.*, 2009) offer new perspectives for future landscape change studies in the region, keeping in mind the potential role of active tectonics.

Seismic hazard

The role of active tectonic processes regarding critical facilities was underestimated at the time of the design of the Gabčikovo-Nagymaros hydropower complex in the 1970s. A similar situation occurred during the re-assessment of seismic hazard for the Paks nuclear power plant, 200 km downriver, culminating in a spectacular, public professional debate (see Balla, 1999; Tóth and Horváth, 1999). Potentially important, major landscape changes of tectonic origin in the Danube Bend were pointed out – although not yet fully discussed – in the 2000s. (1) Rapid late Quaternary uplift of surrounding hills simultaneous with downcutting of the Danube riverbed (Ruszkiczay-Rüdiger *et al*., 2005, Karátson *et al*., 2006). (2) Large-scale changes in river bed morphology documented on maps from the 16th century onwards, suggesting either intense river dynamics or tectonic origin (Székely *et al*., 2009). (3) Rising flood level at the end of the Middle Ages (Mészáros and Serlegi, 2011; Kiss and Laszlovszky, 2013; Kiss, 2019). (4) Recognition of a dense, potentially active fault system in the riverbed (Oláh *et al*., 2014).

While seismicity based on historical and instrumental data are considered pretty well known in the Carpathian-Pannonian region (Tóth *et al*., 2002), new historical data can be found any time. Archaeoseismology – a new method for Hungary – provides further important information on past damaging earthquakes. We suggest that historical seismology and archaeoseismology should be integral part of environmental assessment for critical infrastructure facilities.

Conclusions

An archaeoseimological study was carried out on the damaged medieval Salamon Tower and Franciscan friary at Visegrád in the Danube Bend, Hungary. The site is adjacent to a proposed hydropower station, designed for seismic intensity VI. Features of earthquake-induced fracturing, collapse, and liquefaction indicate that an earthquake of intensity IX destroyed buildings in the town. The event is tied to a properly dated seismic event on 21 August 1541, in Pest, 35 km to the south. Travelogues record that Visegrád was an abandoned ghost town in the decades following this event. Seismic design of any critical facility should include studies on historical seismology and archaeoseismology.

Data and Resources

The Earthquake Catalogue, version 2019 is maintained by the Geodetic and Geophysical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Sopron, Hungary.

Declaration of Competing Interests

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Figure captions

Figure 1. Site of the proposed Nagymaros dam and medieval archaeological sites at Visegrád. Vintage Google Earth image, dated 31 December 1994. The dam construction site is still visible, removed later.

Figure 2. V-shaped collapse damaged all six floors of Salamon Tower as seen in 1870. View from east. The collapse scar on the left was caused by cannonfire on 12 October 1540. Note the vertical fracture along the vertical row of windows – this is an indication of severe seismic shaking. Photograph by Sándor Beszédes (*FKF 52495N)* (Bozóki 2014, fig. 2).

Figure 3. Vertical fissure across all six floors on the western facade of Salamon tower, a clear signal of severe seismic shaking. Pencil drawing by Antal Gregus in 1872 (*FKF 55908N) (*Bozóki 2014, fig. 4).

Figure 4. Franciscan friary at Visegrád. Ground-floor plan of the cloister (after Kiss and Laszlovszky, 2013, modified). The southern wall is 3 m high, other walls are less than 1-1.5 m high. Numbers refer to figures. **5** – floor of the rectangular, covered cloister walk has subsided by about 10-20 cm in average. *6-7* – site of 80 cm subsidence in the NW corner of the cloister walk. **8** – subsided stairs. **9** – beam holes to support a wooden floor.

Figure 5. Excavated profile of subsoil at probe in the cloister garth.

Figure 6. Undulating floor in the southern sector of the cloister walk. Originally covered by bricks, now the underlying plastered surface is visible. View to east. Site 5 on Fig. 4. Archaeological Database (ADB) photo #6699.

Figure 7. Subsided floor of the cloister walk in the northwestern corner. Original floor level marked on left with a green, horizontal, dashed line. Subsided floor marked with inclined, red dashed line. Maximum subsidence is 80 cm, where person stands. A few floor bricks, embedded in mortar, are still in place. Wooden columns, supporting protective roof of the excavated area, replace stone columns, which supported a double vault. The latter collapsed during shaking, due to subsidence of its foundation (raised, between aisles). Subsided, tilted stairs visible behind person (see Fig. 9). View to west. Sites 6-7 on Fig. 4. ADB photo #6705.

Figure 8. 3D model of 0.8 m deep depression in NW corner of cloister. View to east. Grid shows the shape, grey tint marks depth. Pink: preserved bricks. Orange: plaster.Total calculated volume of ejected material is *ca* 14 m^3 in this part of the cloister.

Figure 9. Tilted and subsided stairs 70 cm below thresholds of the doors in the western wall of cloister walk. Top of the stairs was at the upper dashed line before subsidence. 3D model by structure-from-motion photography. View to SW. Site 8 on Fig.4. ADB photo #6724.

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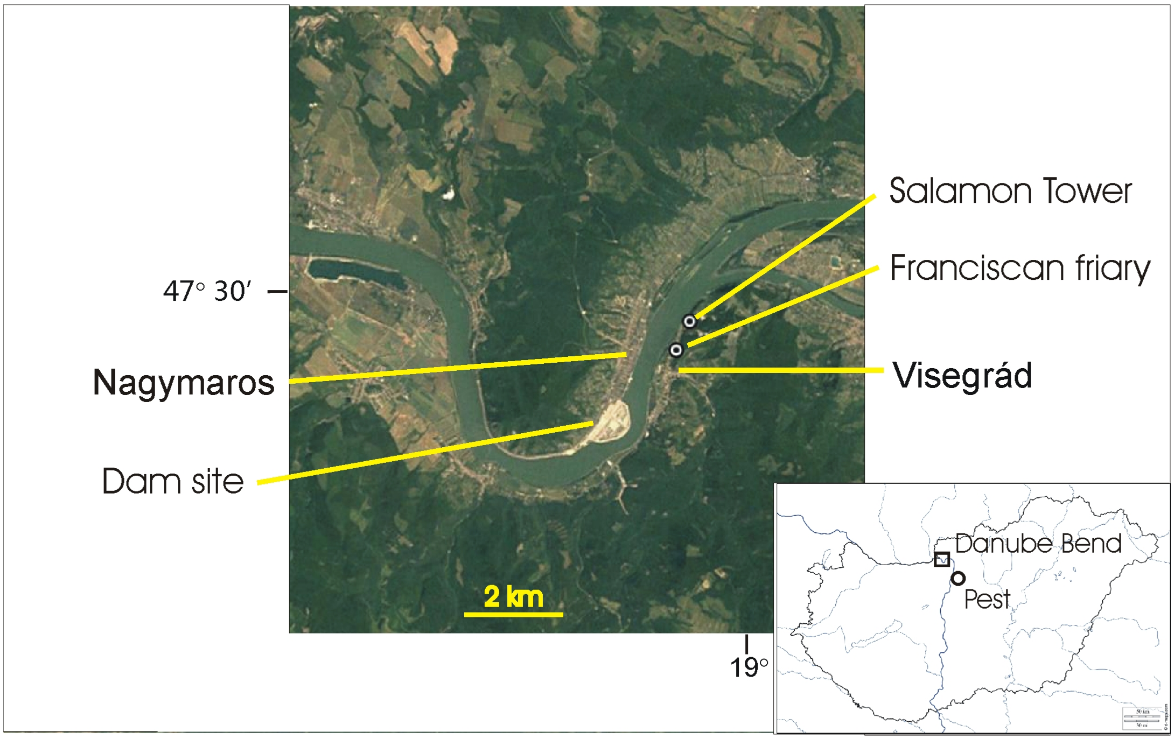

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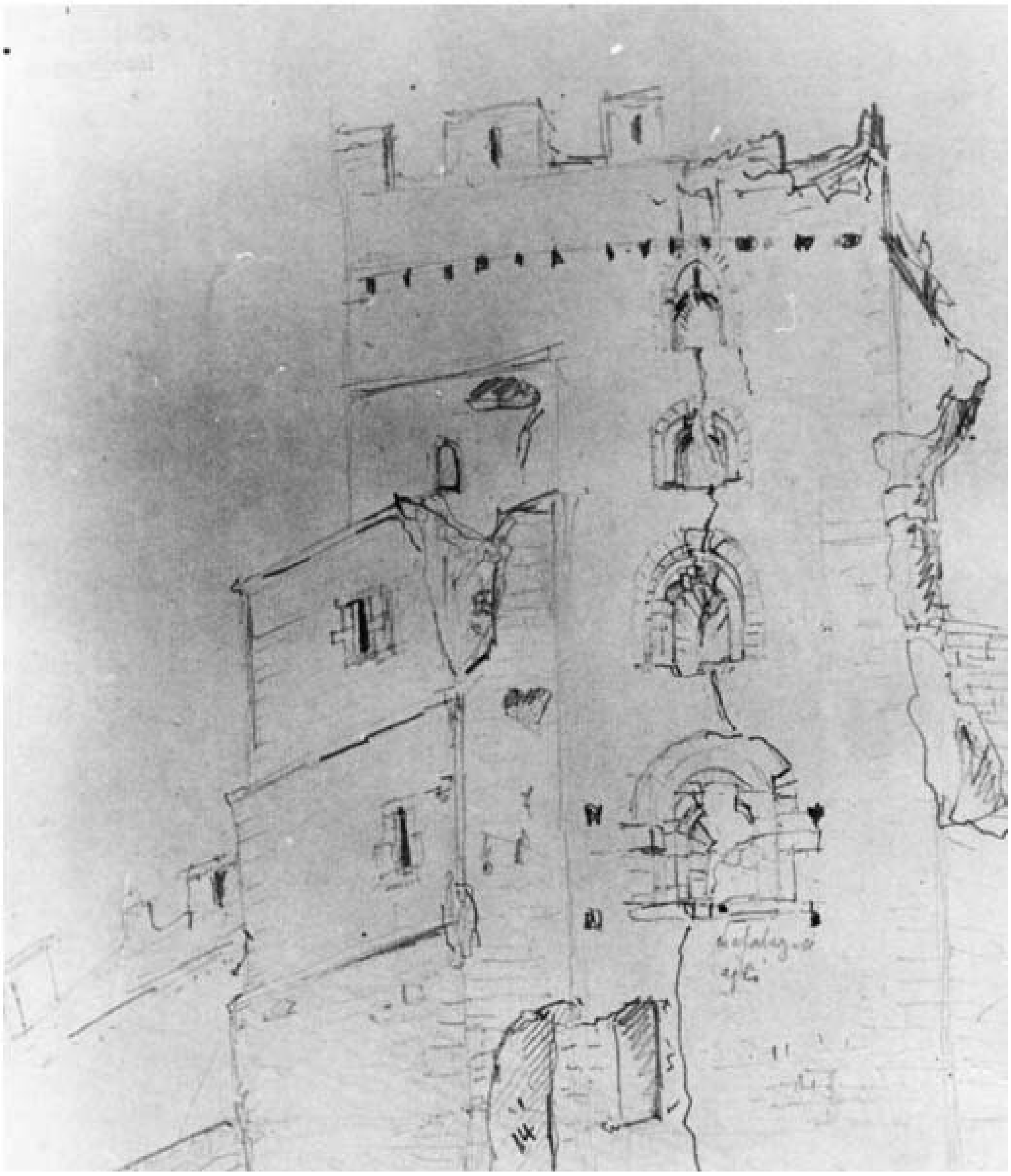

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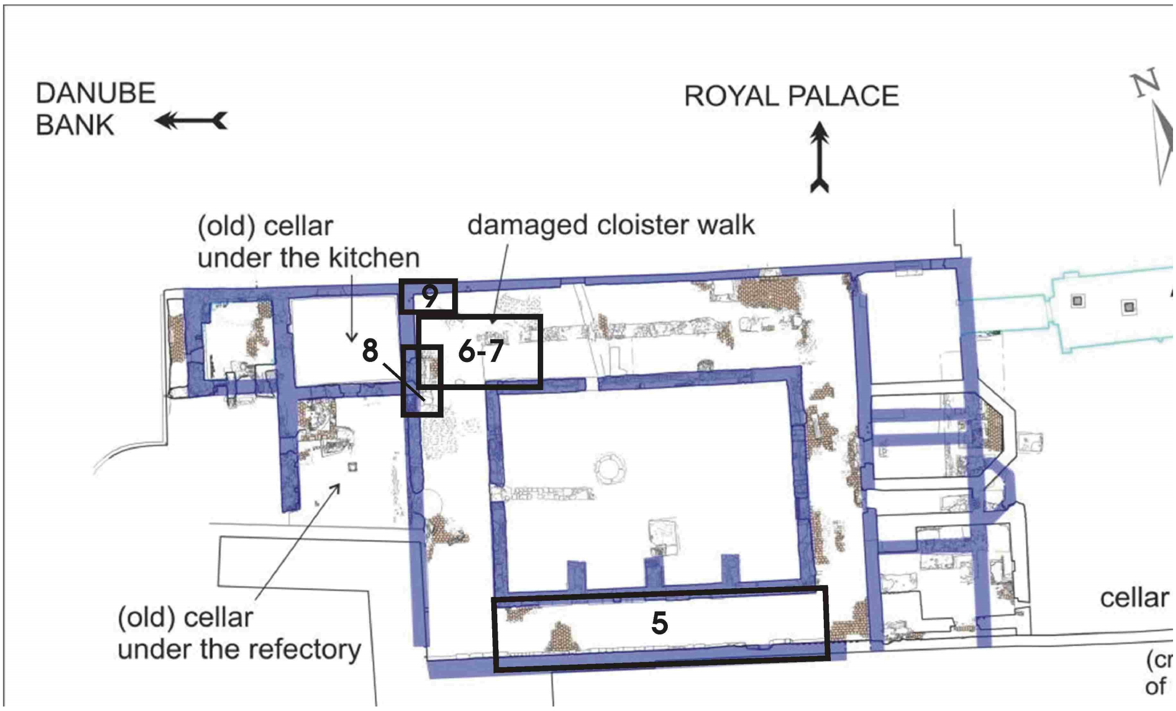

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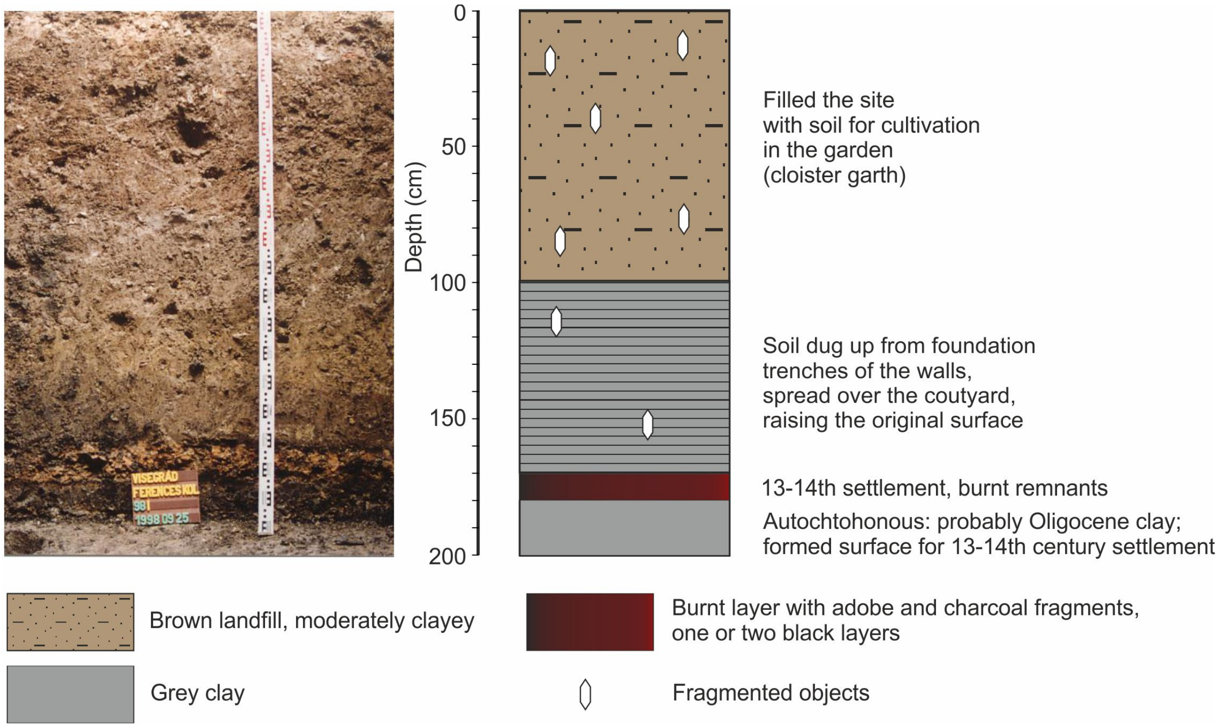

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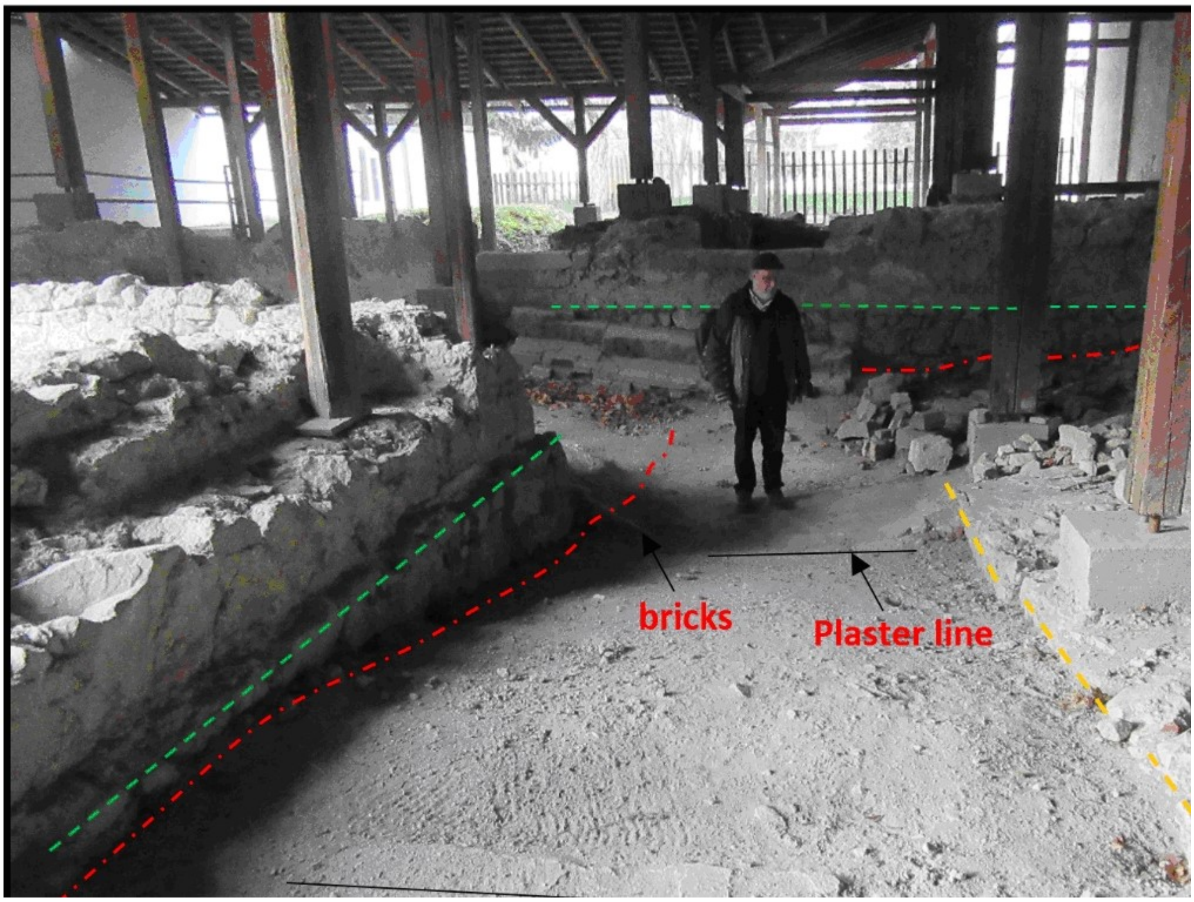

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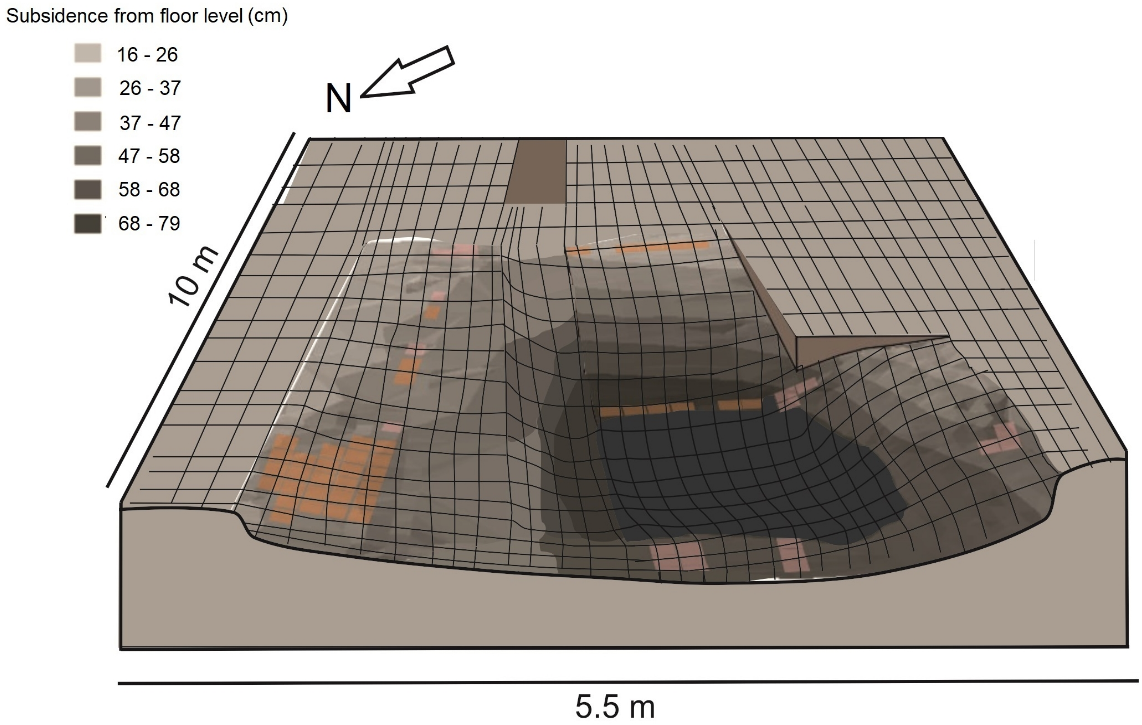

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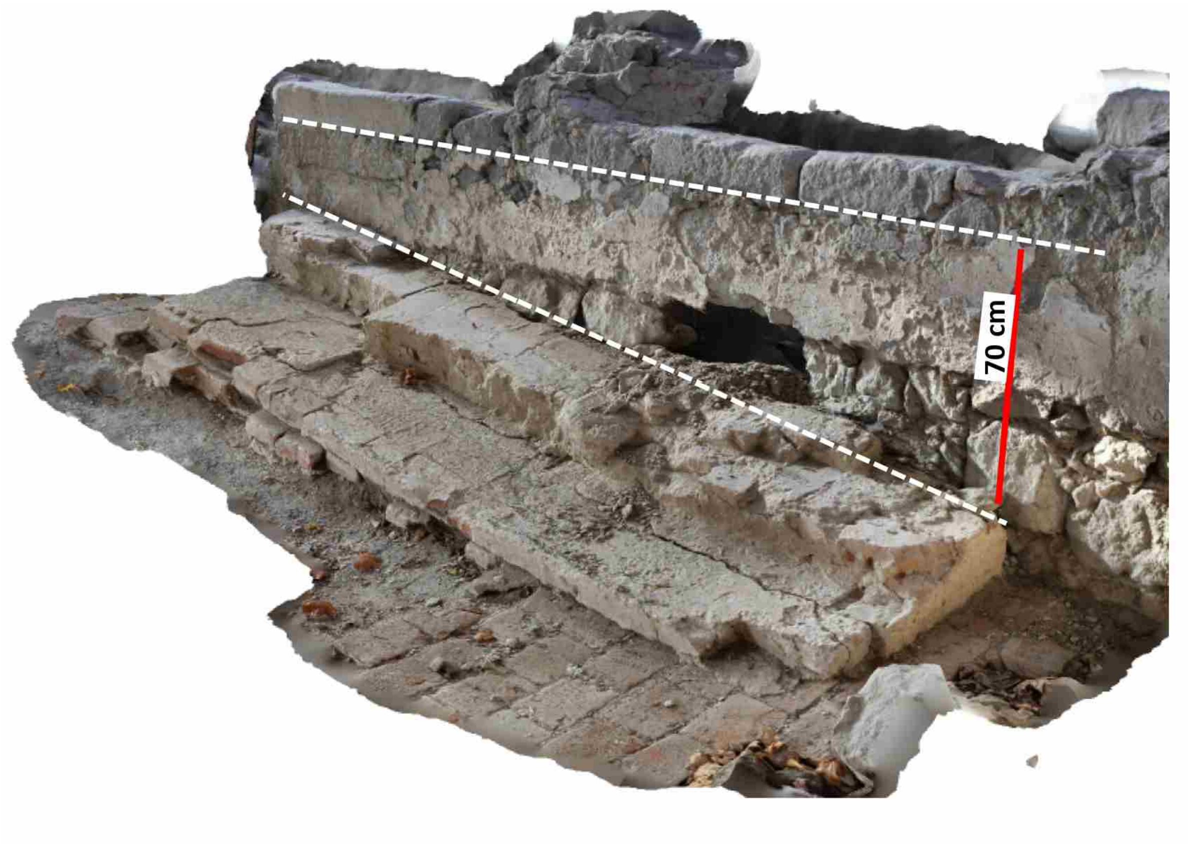

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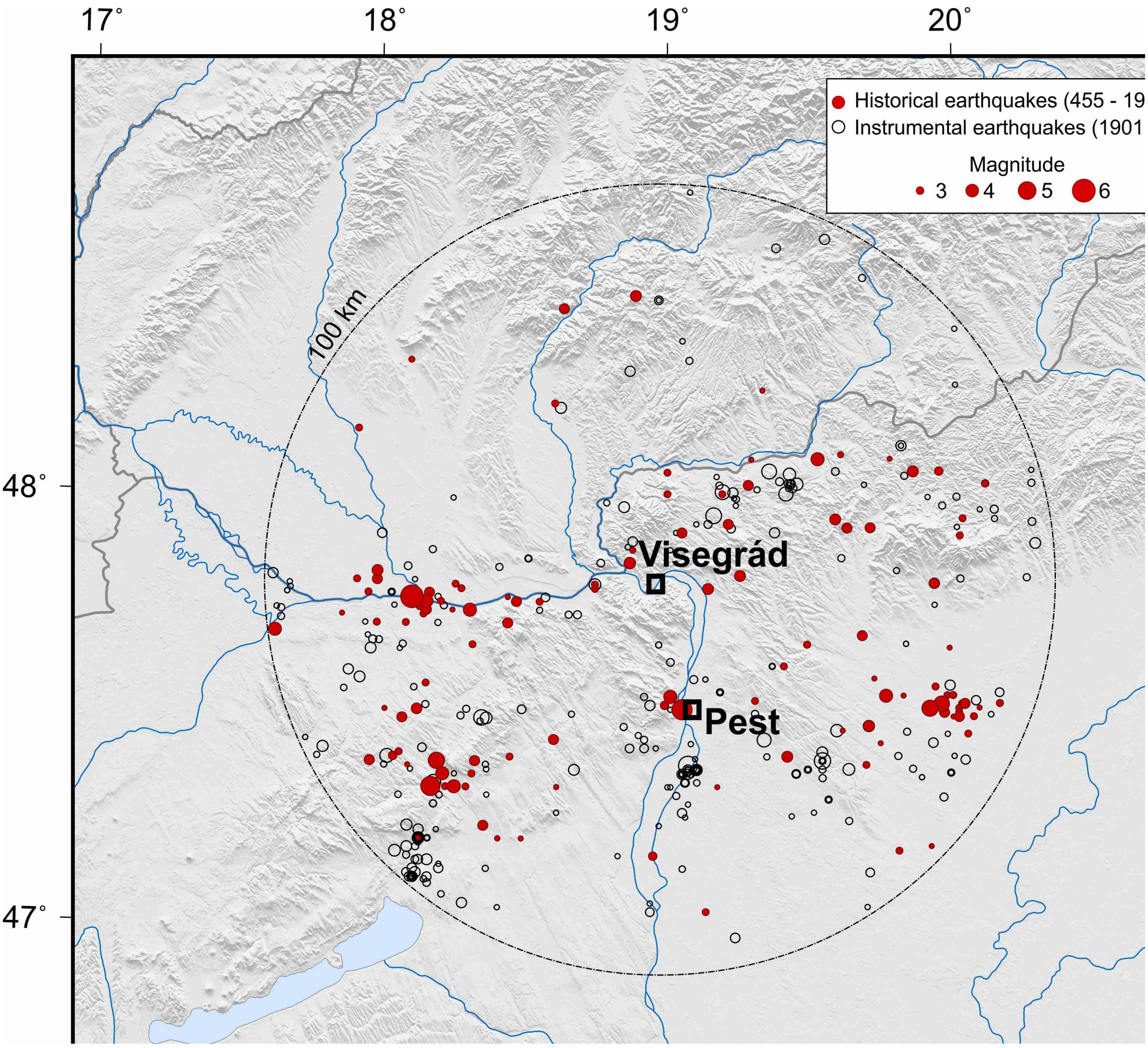

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Table 1. Stratigraphy of subsoil in a probe located in the courtyard of the Franciscan friary in Visegrád (1998).

Depth	Observation	Interpretation
0.0-1.0 m	Brown landfill, with fragmented objects. Moderately clayey.	Filled the site with soil for cultivation in the garden (cloister garth).
1.0-1.7 m	Grey clay, few fragments. Identical with lowermost clay.	Soil dug up from foundation trenches of the walls, spread over the coutyard, raising the original surface.
1.7-1.8 m	Burnt layer with adobe and charcoal fragments, one or two black layers	13-14th century settlement, burnt remnants.
1.8-2.0 m	Grey, fat clay, no finds.	Autochtohonous: probably Oligocene clay. Formed surface for 13-14th century settlement

Table 2. Succession of events in the life of the Franciscan friary to bracket the date of the seismic destruction.

Date	Event	Reference	Implication
15 March 1513	Convent of the province of observant Franciscans in Hungary.	Buzás et al. 1995	Previous construction and reconstruction completed. The whole friary and the cloister part in good shape.
1535	Eight brethren lived in the friary, four of them were priests.	Buzás et al. 1995	Cloister in working order
1539	Names of friary priors are known until this year.	Buzás et al. 1995	Cloister in working order.
1539 summer	King John de Zapolya had the adjacent royal palace repaired, spending the summer there accompanied by his wife Isabel in 1539.		In good order
12 October 1540	Siege of Salamon Tower by Austrian general Velsius. South corner collapses due to intense cannonfire. Troops drink wine of the monastery friary.	Iván 2004:68	No structural harms to friary during military operations
21 October 1540	Velsius gives order to pay the loss of wine to the friary	Iván 2004:69, note #75	Probably in good order, if lost wine was a major concern of the brethren.
21 August 1541	**Earthquake and partial solar eclipse recorded in Pest, 35 km away.**	**Bornemisza (1584) Solar eclipse confirmed by calculations of Kaposvári (2006)**	**This might be the earthquake which destroyed Visegrád.**
Same day	Subsidence of brick floor of the cloister walk, stairs to refectory, and colonnade foundations. Collapse of vault in the northern wing.	Kiss and Laszlovszky (2013)	Cloister part of the friary severely damaged.
	Remains of the columns and collapsed vault are cleared from the northern corridor.	Buzás et al. (1995)	Intent of restoration.
	Repair of sunken floor by erecting a wooden platform above, held by thick beams fitted in nests in the walls.	Own observation.	Cloister still inhabited: access from nothern corridor to refectory is possible again. (Cheap, temporary ways to restore and ensure usability.)
1543	Ottoman warfare against adjacent towns, occupation of Esztergom. Unsuccessful siege of Visegrád.	Iván 2004:70	Brethren certainly fled before war started. Friary suspended/ceased operations.
1544	Ottoman occupation of Visegrád.	Iván 2004:70	Friary went out of use permanently.
1552	Royal palace in ruins	Jovius 1552 *fide* Balogh 1966:226-227; *fide* Pálóczi-Horváth 2014:292	
1587	Town of Visegrád, royal palace, Salamon Tower, all churches and town houses are in ruins.	Leonhard Lubenau (Sahm, 2012)	

	Brick cover of the floor in the cloister walk is robbed. Remaining local population and/or the new settlers of the Ottoman Empire use the remains of the friary (usage of the well in the cloister garth, extraction of brick and stone building material).		Recycling of construction material started. The original function of the church part of the building complex cannot be preserved.
	Graves dug in the corridors. Slow decay of the ruined monastery. Random burials among the sacred walls: graves dug into brickless corridor floors.	Buzás et al. (1995)	The original ecclesiastical character of the whole building complex is not maintained, but some parts of it are still recognized as sacred space by some members of the probably Christian local community.
	Vault of chapter room collapsed, ribs scattered on floor, which already lost the brick cover. Fragments left in place.	Buzás et al. (1995)	Neglect and abandonment.
18th century	Continued robbing of construction material, both stone and brick masonry extensively removed to build the houses of Visegrád. The new German inhabitatnts of the re-settled town did not recognize the original structure and function of the building, they extract material for their village houses.	Laszlovszky (2003).	
	There were still high walls of the palace surviving until the middle of the 18th century, when count Starhemberg, the then owner, had them removed for the construction of the newly inhabited village of Visegrád.		No upright walls of the cloister anymore.Some parts of the wall between the church and the cloister survives as a fence wall between the newly arranged plots.