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Pinpointing a Historical Dew Pond in the Kerekbükk Natural Lake Area, Cserhát Mts., N-Hungary by Geodetic Survey and Interpretation of a Medieval Boundary Charter

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Abstract

The mesa-like volcanic Kerekbükk hill in the Eastern Cserhát Mountains (N Hungary) hosts numerous small lakes linked to postglacial landslides. Double Lake (Kettős-tó), near the mesa summit, occurs in a geomorphologically atypical position and has therefore been debated as potentially artificial, with uncertain hydrological behavior and function. This study aimed to answer these questions by integrating geodetic and geological field observations with archival historical sources. A detailed geodetic survey was used to build a high-resolution terrain model and reconstruct basin morphology to distinguish natural landforms from anthropogenic modifications. In parallel, we examined 13th–14th-century boundary charters and historical maps (18th century to present) to assess landscape continuity and the persistence of local reference points. Double Lake comprises two basins within a shallow west–east trending glen: the western basin is a natural depression, whereas the eastern basin shows clear human modification, including artificial deepening and a small embankment dam. Resistant andesite bedrock enhances hydrological isolation and restricts incision, allowing water retention despite a minimal catchment. Cartographic representations vary through time, consistent with seasonal water availability and changing survey precision. Field reambulation indicates that a Medieval charter likely documents Double Lake as a stable boundary point since the early 14th century. Overall, Double Lake is a hybrid feature produced by erosion and weathering of the lava cap, and human interaction for local water management, likely for the construction of a dew pond.

Keywords

engineering geomorphology, artificial lake, geodetic survey, digital terrain model, historical cartography

1 Introduction

Identification and reconstruction of man-made landscape changes that happened far before the first local maps and the first larger-scale geodetic surveys have been a real challenge today. Kerekbükk is the single mesa-type hill on the right side of the North–South-oriented Zagyva river valley in the Eastern Cserhát Mountains, Nógrád County, N-Hungary (Fig. 1). The valley had been an important migration route back to the prehistoric. Many small lakes are distributed on the slopes of the hill; all but one are characterized by postglacial landslide-derived, natural origin. Archeologists made several assumptions about the man-made origin of that single outlier lake. The primary goal of this study is to determine the origin and history of this lake by integrating geomorphological analysis with geodetic surveying, geological assessment, and historical source evaluation. Specifically, we distinguish natural and anthropogenic components of lake basins, assess the role of volcanic bedrock in hydrological behavior and landscape stability, and evaluate the lake's long-term persistence using historical cartography and medieval boundary records. By combining quantitative terrain analysis with historical evidence, the study aims to clarify the formation of the lake and demonstrate an interdisciplinary approach applicable to similar small upland basins.

1.1 Geomorphology of Kerekbükk

Kerekbükk is a mesa, a relatively flat-topped hill of volcanic origin, more extensive than a butte and less extensive than a real plateau (Fig. 1). Its highest point is a 569-meter peak on the southern side. The length of the line drawn

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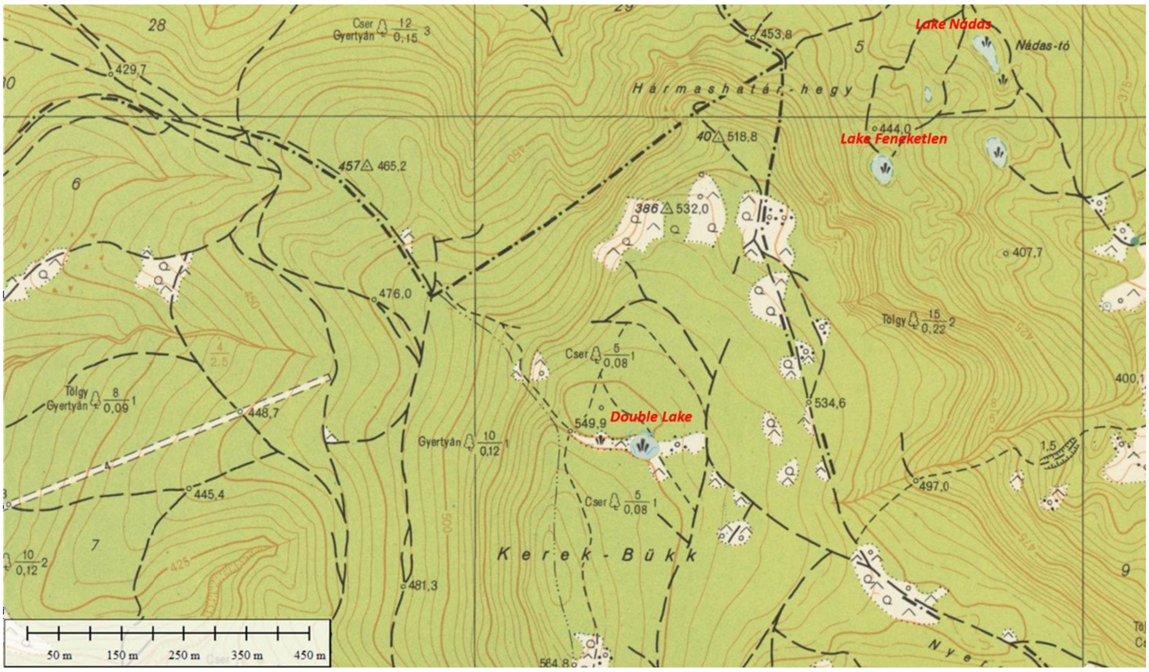

Fig. 1 Topographic map of the Kerekbükk area [1]. Beside the Double Lake on the summit, landslide-derived lakes on the NE slopes, including Lake Nádas and Lake Feneketlen are also visible

along the 525-meter contour line at the edge is 4.22 km, and the area it encloses is 0.65 km^2. The length of the line drawn along the 500-meter contour line is 5.542 km, and the area it encloses is 1.094 km^2, thus forming a plateau of approximately 65–100 hectares, which is generally flat, with smaller elevations and an irregular shape. Cliffs and rocky mountain slopes border the plateau to the west, north, and east, while the slope is less steep towards Mátraszőlős in the south-southeast direction, which is likely why this area belongs to this village.

1.2 The lakes of the Kerekbükk area

Small mountain lakes characterize the Kerekbükk area, typically at elevations of 400–500 meters above sea level.

The first detailed graphic representations in this area were the military survey maps of the Habsburg Empire, initiated in the second half of the 18th century, and the cadastral maps from the mid-19th century. The Hungarian works of the 1st military survey of the Habsburg Empire were carried out between 1782 and 1785. The map is at a scale of 1:28,000. This map is the first and served as the basis for subsequent maps, though, e.g. for our region it is quite inaccurate [2]. The map sections of the 2nd military survey depicting Hungary were created between 1819 and 1869, with several interruptions. The map of the Zagyva Valley, located south of Salgótarján, was completed in 1855. It is considerably more accurate than the map from the first survey and contains more place names [2]. The mapping of the 3rd military survey began in 1869 and took place in Hungary between 1872 and 1885 [2]. None of these three basic maps shows any of the lakes in the Kerekbükk area.

The lakes are mostly unnamed on recent cartographic representations, except for Feneketlen Lake and Nádas Lake. The latter contains a small peat bog and was the subject of detailed postglacial paleoclimatic reconstruction studies [3, 4].

The bulk of the lakes are described as natural, postglacial landslide-derived lakes [3, 4]. Undrained basins formed by landslides represent a distinctive geomorphological feature. These landslides developed along the lithological boundary between the Garáb Schlier Formation [5] and the Tar Dacite Lapilli Tuff [6] no earlier than 15,000 years ago [3, 4]. Similar landslide-related morphologies have been described in many places across the Carpathian-Pannonian region [7, 8].

1.3 Geology of the Kerekbükk

The geological formations of that part of the Cserhát Mountains were formed in the Middle Miocene. Kerekbükk has a characteristic stratovolcanic structure: at its base lies the clayey marine sediment of the Garáb Schlier, assigned to the Carpathian stage of the Middle Miocene and locally reaching several hundred meters in thickness, overlain by various volcanic rocks approximately 15–16 million years old, like the Tar Dacite Lapilli Tuff and the Nagyhársas Andesite [9].

The uppermost surface of the hill is covered by massive lava rocks of the 15-million-year-old Nagyhársas Andesite formation, which has protected it throughout its history from weathering and erosion. [10, 11]

2 The Double Lake

One lake, however, the one in focus of the current study, could hardly be identified as landslide-derived due to its geomorphological and geological position.

In size, it is like the others but is to be found in a special geomorphological position, close to the today abandoned summit on the mesa, a few hundred meters from the vestiges of the ramparts of a Late Bronze Age fortified settlement [12] and about one km from the archaeological remains of a former Árpád-period village [13].

The lake first appeared on a military map surveyed in 1928 [2, 14]. That map, created during a new topographic survey, is more accurate than the previous one. It also gave the topographical base map for Jenő Noszky's geological map of the Cserhát Mts., including Kerekbükk [11].

Geomorphologically, the lake was first described in 1960 as a natural lake. "The slope is very gentle, and in the flatter parts, even a tiny, undrained depression can develop. The depression formed a temporary lake." [15]

Later, in the 1990s, castle explorers mapped the area and uncovered the remains of a Bronze Age fortified settlement and assumed the lake to be artificial [16]. They, understandably, believed that it originated in the Bronze Age. Similar drainage ponds can also be found in other Bronze Age fortified settlements [17]. In England, many of the dew ponds are found inside or in close association with Neolithic and Bronze Age earthworks [18]

The lake was named during a detailed geomorphological survey of the area in the early 2000s [19]. Its name "Double Lake" (in Hungarian: Kettős-tó) refers to the two adjoining basins of the lake, hereafter referred to as "western" and "eastern" basins.

3 About dew ponds

Dew ponds are artificially constructed, shallow basins occurring mainly in upland regions of north-western Europe, especially in southern England. They function as small water-retention features that provide drinking water for livestock in areas lacking permanent natural freshwater sources [20].

Although the term "dew pond" first appeared in the Oxford English Dictionary in 1865 [21], documentary evidence dates their use in England to at least 825 CE, and their construction may extend back to the Neolithic or Bronze Age [22]. Despite their name, reflecting the historical assumption that these ponds were supplied mainly by dew, these ponds were primarily designed to collect and retain precipitation. The limited tendency of these ponds to desiccate is explained not solely by a positive water-input–evaporation balance, but primarily by the presence of aquatic vegetation [23].

Historical dew ponds have also been reported from a limited number of places in the Carpathian-Pannonian region from the Late Bronze Age [17].

4 Methodology

4.1 Geodetic survey

For the proper engineering geomorphological characterization of the Double Lake and its neighborhood, we carried out a detailed geodetic survey.

As base of the geodetic survey, three reference points were established around the lake. The points were permanently marked by head bolts built into concrete cylinders with 60 cm height and 12.5 cm diameter (Fig. 2). Attempts were made to determine the points using RTK GNSS measurements, but because of the unstable internet connection and satellite obstruction caused by the trees, only one point (with id 3) could be successfully measured. Thus, two further auxiliary control points were determined using RTK GNSS and the other two reference points were determined from GNSS points using a total station. The RTK corrections were obtained from the Hungarian national RTK service (gnssnet.hu). The final coordinates are in the official Hungarian map projection (Hungarian EOV) and have an accuracy of 1–2 cm (Table 1).

Fig. 2 One of the reference points at the northeastern side of the lake with the dam in the background (looking south)

Table 1 EOV coordinates of the reference points

Point	Easting [m]	Northing [m]	Height [m]
1	696279.86	294577.353	548.752
2	696260.27	294526.274	550.155
3	696216.79	294567.425	548.703

Detail points were taken from the reference points using a total station. The topographic points were taken every few meters in an irregular pattern. Points along the waterline and the characteristic features of the presumed dam/embankment were also measured. In total, about 450 detail points were measured.

In addition to geodetic surveys, drone photogrammetry was also applied to develop orthophoto and point cloud. Even though the mission was completed in early spring, due to the trees, just a low number of terrain points could have been taken; therefore, the point cloud is not dense enough to develop a high-quality terrain model. Orthophoto can be used mainly for visualization (Fig. 3).

4.2 Archive and perambulations

As the region lies outside of the Roman Limes, no wonder that the earliest written sources about this area date only from the 13th–14th century. In medieval times, due to the lack of accurate topographical maps, the boundaries of settlements were defined through perambulations, where official persons walked along the borders, accurately describing them. The borders could be marked by natural objects, such as cliffs, peaks, streams, or larger trees, or by artificial objects made of earth or stone. These perambulations were documented in official charters, which proved ownership of the land.

In this area, we are aware of one of the charters that outlines settlement borders [24]. To explore the medieval borders, we sought to identify the geographical locations described and names used by creating a comparative chart. The correctness of the chart was justified in the field by complete reambulation of the tracks described in the charter.

Fig. 3 Orthophoto of Double Lake 2020

4.3 Geological survey

We carried out detailed surface geological mapping on the 1:10 000 topographical base map scale of the Kerekbükk hill [25].

Though the final complex map hasn't been published yet, here we use a part of it that refers to the close vicinity of the Double Lake.

5 Results

5.1 Digital terrain model

By accurately mapping the surface landforms, we aimed to clarify the relationship between the two lake basins. Based on geodetic survey, a TIN (Triangulated Irregular Network) was developed (Fig. 4). To visualize the terrain, contour lines were generated at 0.25 m intervals. The reference and detail points, the contour lines, waterline, dam/embankment and other features were depicted in a digital map with a scale of 1:400.

The projected coordinates (EOV system) of the lake are 696265.769, 294561.822, with an elevation of 548–549 meters above sea level.

It is situated in a gently sloping valley that runs west to east, nestled between two modest hills atop the mesa, and relies solely on rainfall for its water supply. The eastern lake basin area is approximately 1442 m^2, with a perimeter of 147 m, while the western lake basin is 1456 m^2 with a perimeter of 152 m, both enclosed by the 548.5-meter altitude contour line. At higher water levels, the water surfaces of the two basins merge. Due to the geomorphological conditions, the bottom of the western part is marshy. The data confirm the presence of a dam, bordering the lake to the east, at approximately 548.6–549.0 meters. The total extent of the two lake basins at the 548.75-meter altitude contour line is 3170 m^2, with a perimeter of 321 m. However, the water may overflow at this level, as a recent forestry road next to the lake has damaged the dam. The bottom of the eastern lake basin is practically flat, as observed in an extreme dry season in 2022 (Fig. 5).

5.2 Geology of the vicinity of the Double Lake

Our detailed survey (Fig. 6) shows that the Double Lake is located in a relatively simple geological position, without significant tectonic disturbances. It is lying on the slightly (1°) SE-dipping surface of a massive lava rock area of the Nagyhársas Andesite Formation, topping the mesa. On the other hand, by the increasing elevation westward, the lava layer is getting thinner, sometimes departed in situ in larger blocks, giving way to the surface

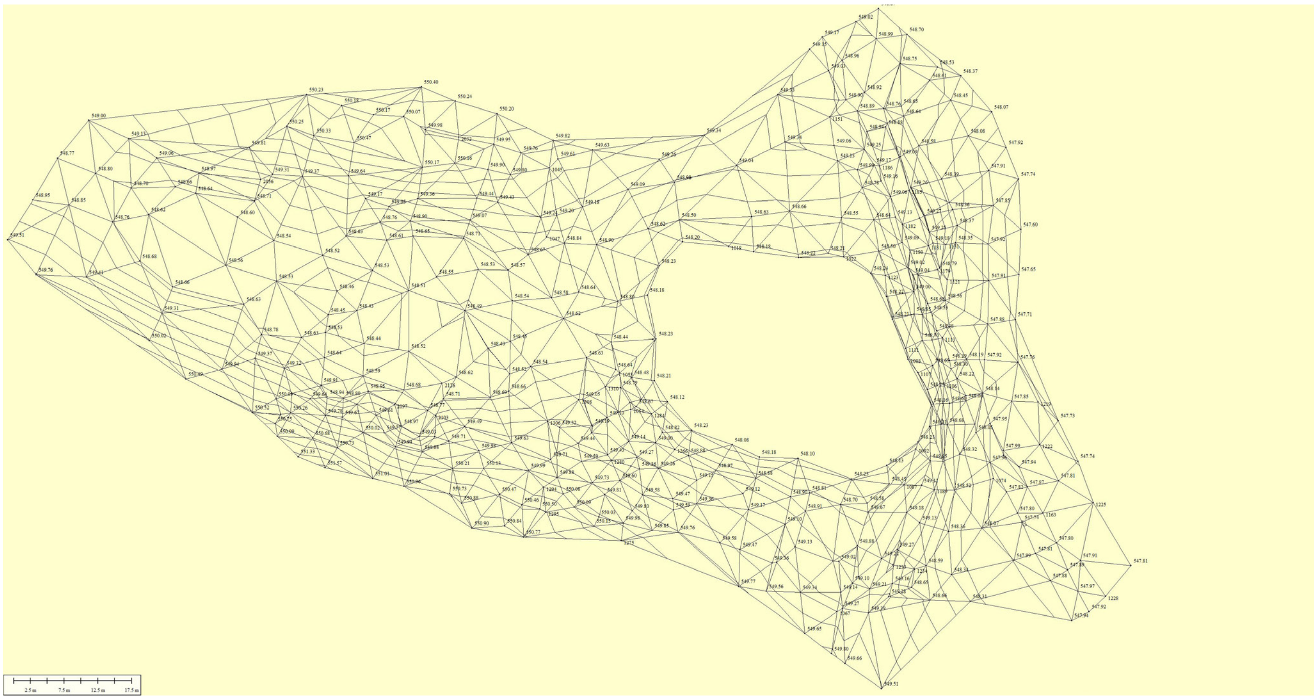

Fig. 4 The geodetic survey map. The eastern lake basin, containing water, is clearly visible, while the western one, dry in that period, is indicated by the bottom morphology only (see also Fig. 8 below).

Fig. 5 The dried, flat eastern lakebed in the arid summer of 2022 (looking east)

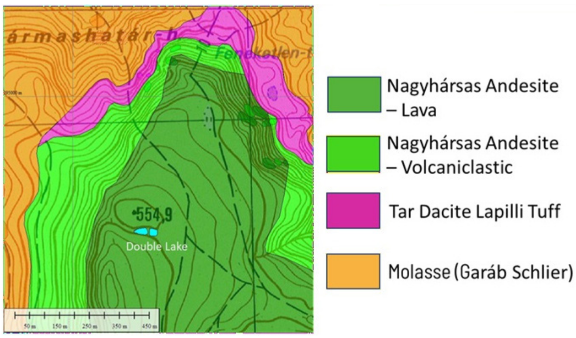

Fig. 6 Geological map of the Kerekbükk area

for the underlying volcanoclastic facies of the Nagyhársas Andesite Formation.

5.3 Exploration of charter sources

Our key charter [24], issued in 1327 by Charles I, Hungarian king, mentioned a "lake" at the top of a mountain. This charter pertains to the donation of the Castle of Hollókő, situated 10 km west of the lake, and outlines the boundaries of its estates. According to the description, "the boundary reaches the top of Sátoros Hill, where a stone boundary marker next to a lake separates the estate of the church of Garáb from the west, the estate of Szőlős from the south, the area of Bárkány from the east, and the area of Almás, which belongs to Hollókő, from the North."

As there are several lakes in the area, in earlier studies [26], it was not clear which one was indicated in the boundary description. However, during a personal inspection of the borders described in the document, it became clear that the lake in question could only be the Double Lake.

This is the only lake situated on the summits of the surrounding hills and the only position that can function as a quadripoint for the four neighboring settlements.

5.4 Field inspection of medieval boundaries

Fig. 7 visualizes the property/village borders described in the charter 1327 nearby "the lake". The quadripoint separated the lands of Garáb to the west, Szőlős to the south, Bárkány to the east, and Almás to the north.

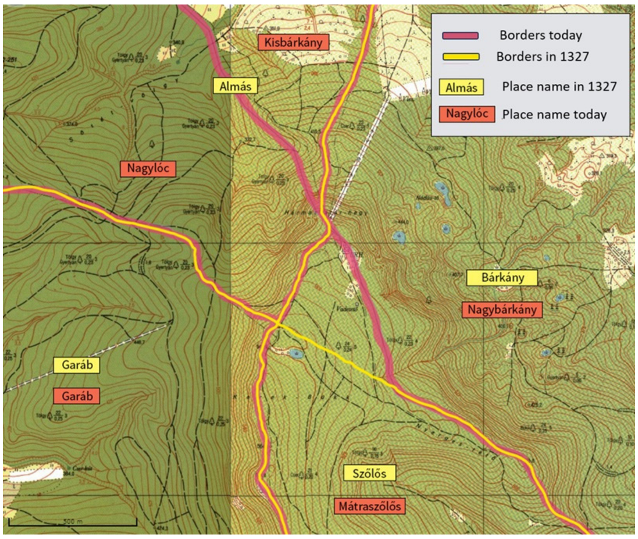

Fig. 7 The settlement borders drawn based on the medieval charter's data, compared to the recent situation [1]

Today's valid village borders run very much along the same lines, with the exception that the original quadripoint has been split into two triplepoints. One of them remained at the original position, next to the lake, separating the lands of Garáb, Szőlős, and Almás. The other one, the junction of borders between Szőlős, Bárkány, and Almás is to be found about 500 meters farther north.

6 Discussion

6.1 The eastern basin

Fig. 8 shows a coloured geodetic survey map, including survey points, together with a cross-section depicting the morphology of the eastern lake basin. The data clearly indicate that the eastern basin is an engineering construction.

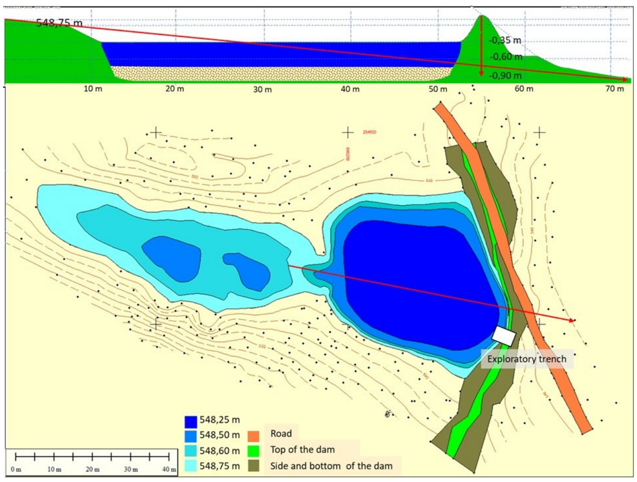

Fig. 8 A coloured map based on the geodetic survey, with a cross-section of the Eastern basin

The constructed dam reaches a maximum height of 0.9 m, corresponding to the natural terrain gradient measured over approximately 50 m. The crest of the dam lies at 548.75 m above sea level; once the water level attains this elevation, the surfaces of the two basins merge, and overflow would occur through the weakened section of the dam. The original structure was likely somewhat higher, as both natural erosion and later human disturbance have contributed to its present reduced height.

The cross-section suggests that the shallow surface soil material cut out on the west side for deepening the basin was used for the construction of the earth dam on the east side.

6.2 The western basin

The western basin (Fig. 7) shows no artificial change in natural topography. A practically flat saddle, located between two rocky heights, hosts a very shallow basin, optimal for wet, marshy conditions at 548.75 m above sea level. The western basin is so small and shallow that, just on its own, without the artificial eastern basin, it would likely never have been regarded as a lake. Even today, the western basin is commonly dry in summer, while the lake in the eastern basin mostly survives the dry periods.

The terrain model points out that the water level of the western basin is not controlled only by the crest level of the dam on the eastern basin, but also by the natural morphology on the west. That water level limitation by the western side morphology suggests that even if we must calculate with some erosion of the dam, there would not have been much sense for the constructors to build a much higher dam than the current one on the east side.

6.3 The role of the charter: when was that artificial basin + dam constructed?

The crucial point in age determination is whether we can use the charter for confirmation of the presence of the lake by the time the charter was issued.

Following the perambulation track itself on the field no question that the border, cited in the charter 1327, leading to the lake, climbs up from west to Kerekbükk.

As a result of the systematic field work, it was recognized that not only that single track, but almost all of the old (13–14th century) and recent village borders coincide (Fig. 7), even though the settlements themselves are no longer of the same name [27].

The single important minor change is that the original, 14th-century Bárkány/Szőlős (today: Nagybárkány/Mátraszőlős) border today turns north-northwest when reaching the plateau from the E-SE. It follows the natural geomorphology, runs along the eastern rim of Kerekbükk, and doesn't cross the mesa towards the lake anymore. That border correction was likely generated by the situation, that the 14^{th}-century property of Bárkány on the northern side of the plateau could not be reached through the steep cliffs, only by crossing the southern mesa part, which belonged, ab ovo, to Szőlős. We don't know when exactly – after 1327 – that border correction happened, but on a map of Kisbárkány dated for 1868 [28], we can find the current border situation already. The peak itself, where that new, northern junction lies, has been named as Triplepoint (Hármashatár) sometime before 1928 [14].

Our analysis above shows that the borders of Garáb, Szőlős, Bárkány, and Almás could meet in the 14^{th} century directly only beside the Double Lake, generating a quadripoint, and thus the medieval border description could be brought into concordance with the recent maps.

The only further controversy is the name of the hill in the charter: "Sátoros". On the recent maps, Sátoros is the name of a smaller, adjoining, but separate hill east of Kerekbükk. Its steep peak and slope morphology doesn't allow the presence of a lake on any part of that hill.

By a systematic historical evaluation of the geographical names, including the hill names in the historical maps mentioned above and comparing these name variations with the names in the charter, it became clear that while the geomorphology remained the same, some of the hill names disappeared, some of them, including the "Sátoros", migrated to other hills, while several new names, including the "Kerekbükk" arose during the many centuries.

The available historical source base is currently limited to a single charter; however, since the number of newly discovered documents is growing, additional medieval or early modern documents pertaining to the area may possibly be identified in future research.

Based on that analysis, we can state that the Double Lake dam is a Medieval or pre-Medieval construction, not younger than 1327. For more precise age data, further science-based age determinations are in progress.

6.4 Why did they construct that water management facility?

The last open point to be discussed is the purpose of that, a minimum 700-year-old engineering geomorphological feature.

Kerekbükk is the sole mesa-type hill in the vicinity. The forest-surrounded plateau of the hill had offered excellent opportunities for livestock farming for centuries, not too far from trade routes, yet in a separate and protected location. The only limiting factor of that activity was water, as no springs or permanent lakes were present on the plateau due to the geology-connected geomorphology and hydrology. Creation of the artificial lake provided a permanent source of water, a dew pond.

7 Conclusions

In the Kerekbükk lake region (Cserhát Mts., NE-Hungary), characterized by landslide-derived lakes, we could decipher the origin of the Double Lake, a lake situated in a very unusual position, close to the hilltop, on a slightly dipping mesa stabilized by a thick andesite lava layer.

Double Lake is a composite phenomenon: its western, very shallow basin is completely natural, while its eastern basin is entirely a product of sophisticated Medieval, or even pre-Medieval, engineering activity: a shallow valley, gently sloping toward the east–southeast, was artificially deepened and closed by a dam.

The formation of the lake was enabled, on the one hand, by the geological characteristics of the hill. The thick andesite lava forming its uppermost layer exhibits very low permeability, which effectively prevents precipitation from infiltrating into the subsurface. On the other hand, the plateau-like geomorphological conditions made it possible to establish a 50 m long artificial lake by removing no more than approximately one metre of surface soil and erosion debris from the shallow valley and constructing a small, but effective earth dam.

The settlement border descriptions preserved in medieval charters were reconstructed based on field observations. The geographical features referenced in the perambulation records were systematically identified, demonstrating that medieval settlement boundaries largely correspond to their present-day counterparts, at least in the target of this study, while also documenting instances of divergence.

It was determined that the lake mentioned in the charter of 1327 is identical to the present-day Double Lake. Earlier researchers studying the lakes in the area were uncertain about this identification; however, field inspection of the borders described in the charter made the correspondence evident.

The method used demonstrated how historical cartography can be extended to periods well before the times of modern geodetic surveys and maps.

Acknowledgement

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