Abstract: Although fertile soil is rare in central Slovakia, the region is rich in raw minerals, a resource exploited since the Palaeolithic. Maintaining trade through a reliable network of safe routes across the mountainous landscape was of vital importance, and the remains of roads that connected this mining area to the rest of the world can still be found. Furthermore, the south–north route connecting these resources with the Carpathian Basin in the south and the Vistula River Basin in the north may have played an important role as a possible bypass to the well-known Amber Road. By combining walkthrough surveys and high-resolution LiDAR data, the paths of single roads can be reconstructed and analysed in relation to the main routes. Furthermore, by applying the geographic information system-based spatial context of settlement structures, analyses can be performed on whether routes passing through certain areas caused the establishment of settlements or whether the routes were built to connect the established sites with the rest of the road network. Finally, defining ancient route planning strategies can help answer the question of how the main routes affect settlement patterns.

Keywords: prehistory, Middle Ages, old routes, spatial analysis, the Carpathian Mountains

1 Introduction

Carpathian Mountains are a geographical and a cultural border land. Fertile soil is scarce in the mountainous area. Yet the landscape is filled with archaeological evidence of the dense settlement structure including large hillforts. The question is what was the reason all the people through centuries were drawn to settle in these mountains? What was the source of sustenance for all of the people in the large hillforts? Could it be only the exploitation of raw materials? Some of the sites are too distant to have access to the raw materials. Trade and mobility come into mind as an explanation. But could it be proven? The aim of the following text is to find an answer to this question using spatial analysis to figure out the connection between ancient routes and the settlement structure especially in the area of Central Slovakia between the northern edge of Carpathian basin and the upper River Váh in the North. The chronological scope was set in the time frame from chalcolithic to the end of Middle Ages.

During the survey of the UNESCO site, Historic Town of Banská Štiavnica and Technical Monuments in its Vicinity, preserved old roads in the mountains surrounding Banská Štiavnica were documented. Most of these roads seemed to demonstrate the specific south–north pattern, and, upon further investigation, a
A transportation corridor emerged, crossing the Northern Carpathians in the central part of today’s Slovakia (Figure 1) to the east from the corridor of the Amber Road (Miño, Fratričová, & Rusko, 2020, pp. 55–56). Some authors have noticed that it is possible to trace a south–north route passing this region based on medieval written records (Hanuliak, 1996, p. 443; Ivanič, 2011, pp. 73–74). These records concerning routes and roads in the area of Hron and in the Ipeľ River catchment area were previously summarised by Ivanič (2011). These data were also partially interpreted through the simple and direct linking of the topographic points mentioned in the written sources, thus framing a net of vectors outlining the basic directions of the roads (Figure 2). However, no attempt has been made to analyse the terrain. The earliest written record concerning the road network in the researched area is considered the foundation bulla for the monastery of Bzovík, which dates to 1135 AD; it determines one of the boundaries to its lands through a certain Magna via (e.g., Ivanič, 2011, p. 50). This route is mentioned in demarcation documents of various settlements throughout the 13th century (Ivanič, 2011, pp. 50–52). Some of these records were already known to Hanuliak (1996), who tried to outline the route by directly linking it to the sites of important 13th-century administrative, defensive, and sacral buildings, such as castles, churches, and monasteries. The route reconstruction extended beyond the Hron and Ipeľ regions to the north toward the present-day Slovakia–Poland border (Figure 2).

A few attempts were made on a local scale to determine the exact paths and document old roads in the terrain, evaluating them in terms of the direction, importance, and date. These include several areas in the vicinity of Pustý Hrad (Deserted Castle) in Zvolen (Pažinová, Beljak, Slamová, Beláček, 2013; Slamová, Beláček, Beljak, Pazinová, & Chudy, 2014); the hub in Zvolen, which is connected to the sources of raw minerals (Miño, 2019, pp. 7–8); the interconnection between the royal towns of Kremnica and Banská Bystrica via the Kremnické Mountains (Kvietok, 2014, pp. 91–92; Tomeček, 2015); the communications in the vicinity of Ľupča Castle (Miño, 2017, pp. 18–19; Tomeček, 2017, p. 19); the passage through Low Tatra Mountains (Kvietok, 2014, p. 95; Miño, 2006, p. 2) and the Big Fatra Mountains (Kvietok, 2014, p. 96); and the previously mentioned old road system of the Štiavnické Mountains (Miño, Fratričová & Rusko, 2020, pp. 55–56). These surveys were based primarily on terrain recognisance but provided limited data about the dating of the routes.

One of the most important routes researched in this article is the Lower Šturec Pass near the copper mining site of Špania Dolina. Although precise dates are not yet known, there are indications that it is a
passage used in the prehistoric and high medieval periods. Small-scale excavation in pass with preserved hollow ways has brought prehistoric and medieval pottery as well as medieval coins. Other important finds mentioned in this article come from Hiadeľ Pass, which is dated to the Chalcolithic (Kvietok, 2014, p. 95). Hiadeľ Pass is considered as the main gateway through Nízke Tatry Range in the studied time frame. In addition, the inexact dating of prehistoric finds from the vicinity of the Kráľova Studňa (Kings Well) spring in the Big Fatra Mountain ridge might be linked with the passage to the northwest part of the researched area (Kvietok, 2014, p. 96); there is also a possibility they are connected with a pathway leading towards the Vlkolinec–Sidorovo hillfort near the ford on the River Váh and are thus relevant.

The researched region has been important in the mining of natural resources since prehistory, with a focus on silicate minerals, copper, and silver. For example, copper from the Hron River Valley was mined from at least three sites since the Copper Age, and it is known to be exported to the Carpathian Basin to the south and as far as Scandinavia to the north, with related finds in the Vistula Basin (e.g., Kiss, 2020, pp. 317–318; Nørgaard, Pernicka, & Vandkilde, 2021; Wilk & Garbacz-Klepka, 2016, p. 36). Meanwhile, the silver mined around Banská Štiavnica in the Middle Ages was shipped not only to the royal seat in Buda (today’s Budapest) but also further afield to Venice via the Dalmatian route (Štefánik, 2018) and to Poland in the north (Hunka, 2013, p. 31). The transportation of these goods is believed to be the reason why the route through the mountains via Hiadeľ Pass was established. The long-distance route was connected with the mining fields via the Lower Štorec Pass. Another factor for establishing a long-distance route in this area during the medieval period could be to achieve the shortest distance between the Hungarian and Polish capitals (Buda and Krakow, respectively) for diplomatic reasons.

A high concentration of archaeological sites especially hillforts has been detected in the region, with the hillforts considered the largest in the broader area of central Slovakia. The mere existence of hillforts cannot simply be explained by the control of natural resources because some of them are located a considerable distance from any significant mining activities. Even arable land was sparse in most of these areas: the terrain, soil quality, elevation, and the contemporary agricultural technology compared to the estimated population of the hillforts and the sizes of the adjacent lowland settlements. Thus, a question arises as to whether the presence of the long-distance routes could be one of the most important factors for establishing at least some of these hillforts, if not the primary reason. Could the economy of these sites be

Figure 2: Map of the medieval road system in the researched area according to written records compiled by Ivanič (2011) and reconstructed based on the distribution of important architectural features (Hanuliak, 1996).
based on toll, trade, and traveller care? How much could the existence of a road affect the settlement strategy in a mountainous environment where the physical subsistence of individuals is more challenging than in fertile lowlands? These are questions that this research aims to answer; to do so, an approximation of the past road network must be reconstructed based on physical evidence.

2 Materials and Methods

The extent of the research area is outlined by the Banská Bystrica Self-Governing Region, which is under the jurisdiction of the author serving as its heritage officer; most of the field surveys conducted by the author are limited to this territory. The spatial outline was refined by settling on the most important and probable destinations for long-distance travel in the past within the Banská Bystrica Self-Governing Region or crossing it. The research specifically targeted the south–north routes, as the majority of the old road remains documented by field surveys and medieval written sources were in this direction. The adjacent parts of the Nitra and Žilina Self-Governing Regions were considered in constructing datasets based on published data. However, no significant field survey was conducted in these areas.

The timeframe was from the Chalcolithic Ludanice group until the end of the medieval period; for the region of Slovakia, this covers the battle of Mohacs in 1526. The reason for this broad timeframe is the question of whether shifts of the main routes could be observed over time, which could lead to future research about the factors that may have induced these changes. The Modern Era was not involved in the study, as settlement reduction due to Ottoman wars in the region was the main reason for changes in settlement patterns for almost two centuries. Concerning the Palaeolithic and Neolithic periods, making any conclusions about settlement patterns is not possible due to infrequent sites in the studied area.

Fireplaces without any other signs of prolonged inhabitation found at the Palaeolithic site of the Horná Túňa Cave in the Big Fatra Mountains were previously interpreted as a cave bear hunting party shelter (Bárta, 1965, pp. 99, 117); however, they could still be considered a traveller shelter. This site, along with flintstone from the Krakow area found in the southern sites and limnosilicites from the Kremnické Mountains (Bárta, 1965, p. 81; Cheben & Cheben, 2020, p. 20) and possibly Mt. Sitno (Miňo, Fratričová & Rusko, 2020, pp. 47–49), which was found around the Slovakia–Poland border (Nemergut, 2020, p. 13), may suggest the existence of the established south–north communication routes. However, there is insufficient evidence to further investigate this matter at present.

A similar situation can be observed for the LBK Neolithic period, when a potential south–north route via the researched area may be possible. However, the density of the sites is too low, and one cannot expect to find any Neolithic road remains in the landscape to indicate the locations of the main corridors. There is no indication for the use of wheels before the Copper Age (Burmeister, 2017, p. 69) with the oldest evidence being a sculpture of an oxen-drawn wagon from Radošíná dated to early Baden culture – Boleráz group (Šiška, 1970, pp. 186, 189), and travelling on foot or with animals is more difficult to trace. Hence, finding the remains of routes from the Neolithic or older proves difficult, and the method applied to later periods cannot be used for the Paleolithic and Neolithic, and comparisons with other data in the set are not compatible.

As part of the initial work, a comparison and relation assessment was conducted on seven different geospatial datasets, each representing a different feature relevant to either settlement structure or transportation needs/possibilities. The datasets and their structures are as follows.

2.1 Settlement Structure

This dataset includes several features: site name, period, type of site, and size. As most of the sites do not yet have absolute dates, the periods were determined only in relative dates, which are listed as follows:
The range of site typology (e.g., hillforts, settlements, burials, mines), which was the result of the data compilation, was not specified in advance. The same applies to chronological phases. That is why the Mesolithic and Migration Periods are missing. The size of the sites was grouped into one of five categories:

<table>
<thead>
<tr>
<th>CODE</th>
<th>Size of the site</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Single find</td>
</tr>
<tr>
<td>S</td>
<td>A site smaller than average for the respective timeframe and type if determined (usually less than 0.5 ha)</td>
</tr>
<tr>
<td>M</td>
<td>A site of average size for the respective timeframe and type if determined or a detected site without known extent (usually 1–2 ha)</td>
</tr>
<tr>
<td>L</td>
<td>A site larger than average for the respective timeframe and type if determined (usually more than 2 ha)</td>
</tr>
<tr>
<td>XL</td>
<td>A site considerably larger than average for the respective timeframe and type if determined (the only site of this type is 21 ha)</td>
</tr>
</tbody>
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2.2 Checkpoints

This dataset includes possible destination points, such as historical capital cities or raw material sources, together with points that may determine a road, such as potential river crossings or mountain passes.

2.3 Direct Link

This small dataset represents the direct distance as the crow flies between the main destinations; it portrays the axis upon which the ideal route of the dataset is built (Figure 3).
2.4 Ideal Route

The ideal route dataset is a linear vector that reconstructs the ideal routes between checkpoints by considering various criteria, such as moderate slope steepness, minimum distance from the direct link, maintaining altitude (i.e., avoidance of repetitive or significant ascents and descents), and the absence of obstacles. ‘Obstacles’ is an auxiliary dataset that represents impassable or challenging obstacles such as bluffs, canyon walls, and swamps.

2.5 Old Road Remains

This dataset consists of vectors of different parts of road remains in the landscape derived from LiDAR imagery, field surveys, or both. Remains that were previously validated by the field survey are marked as such.

2.6 Old Road-Related Written Source – Vector

As no older records for this region are known, this dataset uses medieval written records to consider old road networks by directly linking the mentioned sites to acquire basic directions of the mentioned routes. The featured attributes are mentioned sites, name of the road if known, date, and source of the information.
2.7 Old Road-Related Written Source – Point

This is an auxiliary dataset to dataset 6, and it processes written sources based on road networks that mention only one point with no further information to determine the directional vector of the road. The dataset features data as types of sites (e.g., roadway, ford, bridge, and toll), date, and location.

The first five geospatial datasets consist of landscape features recorded in the field and serve as the foundation to identify the most probable past road network in the selected area. By which is meant a model of route networks which respects the passage capacity of the landscape with respect to the recorded settlement structure and preserved old roads. The last two datasets were used as comparative materials to determine whether it is possible to link specific features detected in the field with the written records.

The key destinations to be reconstructed are part of the checkpoint dataset. They were chosen based on the most important raw mineral sources in the surveyed region (limnoquarzite quarries in Horné Pršany, copper mines in Špania Dolina, Poniky and Ľubietová, iron mines in Ľubietová, and silver and gold mines in Banská Štiavnica) and the supposed trade targets. Thus, Budapest and Krakow were considered medieval royal seats in addition to being recorded as the target for trade in raw minerals from the Chalcolithic (e.g. Kiss, 2020, pp. 317–318; Nørgaard et al., 2021; Wilk & Garbcz-Klempka, 2016, p. 36) until the Middle Ages (Hunka, 2013, p. 31; Štefánik, 2018). The vector shortest paths between the key destinations are listed in the dataset ‘direct link’ (Figure 3). These were used as leading axes for modelling ideal route and considering relevant geospatial and archaeological features.

The proposed tracks of the ideal route (Figure 4) were manually created based on (1) the digital elevation model (DEM) assessment, which used the LiDAR imagery produced by Geodesy, Cartography and Cadastre Authority of the Slovak Republic (GCCA); (2) the author’s personal knowledge of the terrain and long-term hiking and trail-riding experience with terrain-related difficulty levels; and (3) the observed

![Figure 4: Ideal route model with known historic river crossings or bridges based on the first (1782–1785) and second (1819–1869) military surveys of the Habsburg Empire (Arcanum Maps, n.d.) and the written records collected by Ivanič (2011) about key mountain passes. DEM by GCCA.](image-url)
risks from the challenges faced by modern horseback travellers (O’Reilly, 2016). Based on the set criteria, more probable tracks were created by prioritising specific criteria in more difficult terrains (e.g., drink water source, seasonality due snow cover, and passability on foot/in saddle or wagon). The ideal route track can be simulated with geographic information system-based computing (such as Least-Cost Path). However, this has yet to be realised and requires further study in order to adjust the results. Conducting a manual assessment of the track brings with it the risk of subjective decisions. On one hand, it might be a source of error, whilst on the other hand, it could be an historic factor that played a role when the old routes were established. Thus, an experimental crossing of the corridor on foot and horseback whilst using contemporary equipment is the next step planned to adjust the presented results. The comparison of results achieved by all mentioned means might become a source for a more precise overview.

The ideal route dataset was compared with the old road dataset. All old road remains exceeding the buffer of 2,000 m from the ideal route and/or leading east–west direction were discarded to maintain the set of most probable pathways that might have been used for past transportation linking the chosen key destinations (Figure 5).

The old roads can be clearly recognised in LiDAR imagery depending on the geology. In soft substratum such as clay or tufa, they have the typical horsetail-like structure of multiple parallel hollow ways (for relief typology, see, e.g., Bolina, Klimek, & Cílek, 2018; Pažínová, Beljak, Slamová & Beláček, 2013, pp. 159–161). Some old roads are not distinguishable from recent farm or logging roads, as they do not have the typical structure; they are recognisable only in the field by the sporadic appearance of wagon tracks (Figure 6). A walk-through survey was conducted in the field to validate the remains interpreted on the LiDAR imagery and to retrieve artefacts for dating. The survey was not aimed on roads themselves but the adjacent landscape as well. The most precise field survey was conducted in the Štiavnické Vrchy within the The historic Town of Banská Štiavnica and Technical Monuments in its Vicinity UNESCO site.

![Figure 5: The ideal route model in comparison to old roads identified in LiDAR imagery and terrain. Possible use of recorded old roads in different time frames.](image-url)
All the roads in this area were validated, and some Copper Age and medieval materials were retrieved (Miňo, Fratričová, & Rusko, 2021). Although a similar intensive survey was planned for other areas, this was not possible due to restrictions brought about by the COVID-19 pandemic. Partial surveys were conducted in the areas around Hiadešské Pass, Pustý Hrad, Špania Dolina, and the Zvolen–Bystrica Uplands, with a focus on the Hamlet Sliac–Sampor area, where the most detailed survey was conducted. This process consisted of a walk-through and collection of surface artefacts as well as a metal-detector survey and an assessment of the relative stratigraphy of the detected hollow way on the Za Krajičkovou site. The main problem in assessing the preserved road sites is fragmentation due to recent ploughing and other activities. Although the continuation of a lane can be assumed by linking fragments together, this is not always possible. For example, fragments of medieval features could be linked with high possibility in Hamlet Sliac–Sampor (Figure 7), thus determining the direction of the road for some distance. But methodological questions were raised for the prehistoric finds at the same site. Is it possible to link the small fragment containing a bronze phalera (Figure 7, feature 6; Figure 8, feature 1) with the green lane containing the finds of malachite copper ore and chipped stone artefacts (Figure 7, feature 1; Figure 8, feature 4)? Is the path heading southeast, or is it only running around the foot of the mountain before turning towards the northeast direction? The next possible remains are located in both directions. If we do not have any additional dating material from these road fragments, then we cannot be certain which might be an extension of the old road or whether the road forks in both directions. The relative stratigraphy of the detected hollow way assessment was conducted at the Zvolen–Dráhy site in the vicinity of the Pustý Hrad twin hillforts/castles, with the aim of determining its relation to the linear earth wall. The analysis revealed that at least one of the recorded hollow ways was used previously before the wall construction as it is restricting the hollow way of the road by being built over it. Whilst all others were used after the wall became obsolete. They are cut into the mass of the wall.

In general, the dating material mainly consists of artefacts (Figure 8), but we currently do not have sufficient dating data from the roads under investigation. In some instances, stratigraphy or context could be used as a dating strategy. Typological dating is possible only for LBA/IA roads covering steep terrain, such as the short zigzag pattern typical in this period, in contrast with the later prolonged ‘S’ pattern (Figure 9).

However, this introduces the problem of determining the chronological relevance of single fragments of old roads. Fortunately, the problem can be partially solved by a proxy solution. This solution consists of comparing the already filtered road remains to the settlement structure by setting a buffer of 500 m around each settlement or single find, and considering that the remains that intersect with this buffer are likely to represent contemporary routes related to the settlement. Some relevant remains might still slip through this sieve, as illustrated by the road passing under the foot of the Vígľaš-Dolné Chvojno Mountain with its LBA hillfort. The topography of the mountain and its surroundings does not allow the road to go near the buffer, yet there is no doubt that this road has some connection with the mentioned hillfort as well as the
Figure 8: Ideal route model with single finds at least some of which might represent items lost or deposited along old roads. Highlighted are latest finds with a documented relation to old road remains: (1) bronze phalera from Sliač–Sampor, LBA, (2) silver coin from the ford on the Hron River in Slovenská Ľupča, 2nd/3rd century BCE, (3) horseshoe from Dobrá Niva, 14th–16th century AD, (4) malachite ore of possible Špania Dolina–Piesky origin from Sliač Sampor, CA/BA.

Figure 7: Horizontal stratigraphy of old road remains in Sliač–Sampor. The only remains dated by finds is shown in feature 6, whose relation to all other remains is unknown. Feature 4 is possibly used in Middle Ages due to its context with the medieval church site although might be of earlier origin. Feature 1 contains a piece of malachite ore of possible Špania Dolina–Piesky origin; it is difficult to date but most likely prehistoric due to its pebble form (not quarried in a mine) and the site being outside the area of later unprocessed copper transportation patterns. This feature could be the oldest, considering the find, whilst it could be the youngest based on stratigraphy, which may be influenced by recent modifications of the terrain.
polyculture settlement with LBA phase Vígľaš–Kostolisko located some 1,700 m to the northwest of the ford on the Slatina River. However, some modern remains of mine roads or coalman roads might be included in the selection, and it is necessary to manually assess each of the filtered road fragments to decrease the probable error ratio. The old roads filtered by this method will be referred to as ‘dated roads’ for the remainder of this study.

By comparing the probable dated old roads to the ideal route dataset, we can determine the most probable remains of old roads used to link selected key destinations in different timeframes (Figure 5). These vectors might be the most accurate estimations of the old road network based on the landscape in particular timescales, and thus, they can be used together with the ideal route model for the most accurate reconstruction of the respective long-distance routes in the landscape.

The relevance of the roads in settlement development was assessed via analysing settlement occurrence around old roads matching the ideal route model. Given that most of the unfortified settlements in the study are not excavated yet and are only known from walkthrough surveys, their internal structures and importance in the settlement network remain unknown. This is why hillforts were used as the main indicative feature. The following features were also considered: (1) physical occurrence of hillforts adjacent to historic routes, (2) density of hillforts adjacent to historic routes compared with the density of hillforts in the region, (3) sizes of hillforts adjacent to historic routes compared with the average size of hillforts in the region, and (4) other sources for the economies of hillforts. Based on this evaluation, the importance of the long-distance road to the economy of the local community was estimated. For the estimation of importance (i), the following equation consisting of summa for all the attributes for every hillfort located along the route was used:

\[ i = (h^1 + f + p - r - a) + (h^2 + f + p - r - a) + ... \]

- \( h \) – hillfort size index (1–4),
- \( f \) – nearby ford = 1/0,
- \( p \) – nearby pass = 1/0,
- \( r \) – nearby raw material resources = 1/0,
- \( a \) – arable land availability = 1/0.

**Figure 9:** Typological differences between LBA/IA roads: (a) zigzag pattern typical of all LBA/IA sites in the region, an example from the Moštenica–Hradište hillfort; (b) prolonged ‘S’ pattern typical of medieval and modern age road remains, an example from the castle at Zvolen–Pustý Hrad.
3 Results

The evaluation of the data revealed that the topography affected the possible south–north routes due to the complexity of the terrain, which consists of four rivers and three mountain zones. Avoiding natural constraints represented by these natural features forced the creation of multiple variations of the route and included ideal routes for different purposes.

From south to north, the most important topographical features represent challenges to establishing a long-distance route. The first key feature is the River Ipľ, which is today part of the international border between Hungary and Slovakia; it would have served as an obstacle for a traveller in the past as well. Although the river itself is shallow and narrow, with a slow current, crossing it can be challenging due to the surrounding wetlands. The approach to the stream and its crossing is possible only in specific locations. There are six fords (Šahy, Ipľské Predmostie, Veľká Ves nad Ipľom, Balog nad Ipľom, Veľká Čalomija, and Slovenské Šarmoty) known to be used through recorded history (Ivanič, 2011, pp. 50–59); five of them overlap the ideal route model for selected destinations in this study (all fords except Ipľské Predmostie). All six fords are surrounded by a cluster of sites throughout prehistory up to the medieval period, whilst the density of settlements decreases significantly as one travels further from the fords (Figure 10).

The north bank of the River Ipľ could still be considered an integral component of the Carpathian Basin. The boundary of the Basin may be located along the southern slopes of the Krupina Plain in the eastern part of the surveyed area and in Štiavnické Vrchy in the western part. The Krupina Plain consists of soft volcanic sandstone and tufa bedrock, in which the flow of local streams and seasonal rainwater incise the walls of deep, steep-walled canyons. Most of the canyons are oriented southwest to northeast, which is diagonal to the desired vector of the researched south–northbound route.

Whilst most of the plain can be considered moderate terrain, these canyons present a significant constraint. This landscape results in a prolonged journey following either the bottom of the canyons, which is accessible only in dry seasons due to the potential for flooding, or traversing the areas between the

![Figure 10: Ideal route model with the distribution of recorded sites in the region.](image-url)
canyons. However, there are few topographical features that allow the canyons to be crossed whilst maintaining the original course of the route. Of the seven hillforts or castles located in the Krupina Plain area, four are located at the following locations: Čabradský Vrbok I-Castle Čabraď located on an LBA hillfort, Čabradský Vrbok II-Táborisko, Čabradský Vrbok III, and Cerovo-Pustý Hrad, and two are located to the east, where the canyons tend to have a more south–north direction. Both hillforts are situated in the vicinity of road remains; Horné Plachtince–Pohanský Hrad is one of the largest sites in the researched area, and it is located along one of the proposed ideal routes. All settlements in the plain are concentrated along the proposed ideal routes. Almost all the sites surrounding the Cerovo–Trpín–Zemiansky Vrbok axis that are not close to the ideal route model form a south–north line along the identified road remains, which might be considered an authentic prehistoric alternative to the proposed ideal route being studied.

Four ranges of volcanic origin are located north and west of the Krupina Plain. Štavnické Vrchy, a stratovolcano, lies to the west, whilst the Javorie Mountains can be found on the north side. North of these two mountains, separated by the streams of the Rivers Hron and Slatina, are Kremnické Vrchy Mts. in the west and Poľana to the east. This region is characterised by moderate slopes on the outside of the original volcanic craters and on the caldera ledges. The caldera’s inner side is typically composed of rocky cliffs or extremely steep slopes that are more or less impassable, presenting a significant obstacle to transportation. In addition, most hillforts are located at the perimeter of the volcanos at points adjacent to possible passages between the volcanos or into the caldera. The settlements are typically concentrated on the higher grounds of river basins between volcanos. Whilst the locations do not seem to form a coherent route at first glance, upon closer examination, a pattern seems to emerge in the basins of larger rivers (Hron and Slatina), with the main settlement clusters located at known river crossings. These might be used in theory as hubs for riverine transportation, though only River Hron is navigable. Even for this river there is only one record for downstream wood floating yet. No ferries are mentioned in the studied area in the selected time frame. The only ferry at Ostrá Lúka recorded in maps of the second military survey (19th century) is located close to a ford specifically mentioned in medieval records and a later medieval bridge currently researched by the author. So there is lower chance of its use in the researched time frame. The ideal route and the road remains have a tendency to avoid crossing the River Hron in this region on the south–north route and instead prefer to cross the Slatina River. Hron is a much broader and deeper stream than Slatina (the upstream part north of the volcanic zone was the preferred route for crossing River Hron, where the river is shallower and narrower). River Slatina, which means ‘wetlands’, is similar to the River Ipleš described earlier. The river runs on an east–west axis, so it is crossed on the south–north route. The vast wetlands and the composition of surrounding mountains make only a few crossings suitable for long-distance routes. Most important are (1) the area surrounding the ford at Zvolen–Krivá Púť containing the second-highest concentration of fortifications in the researched area and (2) Vigľaš–Pstruša.

The last stage of the south–north route under investigation is the most difficult segment in that it can possibly endanger transported goods or travelling personnel, and it is impacted by the seasonality of mountain crossings. This part also has the most challenging river crossings (Rivers Váh and Hron) immediately before and after crossing the highest mountain range in the studied area. Due to their location below the mountains, the streams in this part of the landscape are extremely sensitive to water level increases caused by thawing snow or heavy rains. The water level, together with the rapid stream (River Hron is described as whitewater level WWI; Preložník, Franko, Juhás, & Urbanec, 2005, p. 2), can make fording impossible for days in some seasons. The altitude of the Low Tatras Mountains also contributes to the difficulties in crossing due to the presence of snow cover for several months. Nevertheless, some low-lying passes make mountain crossing possible for a prolonged period, especially in the spring (e.g., the Hiadel Pass was snow free almost a month before Easter in the 2022 season, although the crest east of Prašivá remained covered in heavy snow). Based on archaeo logical evidence, at least two passes have been used since prehistory. The most important of these two seems to be Hiadel Pass, which is located lower on the mountain; single artefacts from different time periods indicate that it has been in use for a longer period of time.

The hillforts tend to be located between the documented and presumed river crossings and mountain passes, potentially allowing them to monitor both the river and the mountain crossings. The best example is one of the largest hillforts in the Moštenica–Hradište area. The LBA hillfort is located at a height of 958 m a.s.l., with a direct
line of sight to Hiede Pass, the documented LIA (Figure 8, feature 2) and medieval (and presumed CA and BA) river crossing at Slovenská Ľupča (Figure 11), and the presumed LBA and LA river crossing at Lučatin. The settlements in this area seem to be located at the bottom of the river valleys and near river crossings.

Some route-related patterns emerge from the analysis of the topography presented earlier, supported by a spatial analysis of hillforts in the region. Of the 97 hillforts in the researched area, most are located as close to the ideal route model as the topography allows. Over one-third – 38.14% – of the total recorded hillforts in the area are within the 500 m buffer from the ideal route, whilst 65.97% of all hillforts are located in the 2,000 m buffer, which, in most cases, is the closest possible location due to topographical constraints (Tables 1 and 2). In other words, the terrain does not allow create a road closer to a hillfort, or there is no location near the road suitable for establishing a hillfort. In some instances, a visible effort was made to redirect traffic from the ideal route closer to the fortification or other checkpoint using a linear wall to bar the way. This is observed at Zvolen–Pustý Castle (Figure 12), Ladzany–Sokol, and the threshold between the Carpathian Basin and the Carpathian Mountains on the Bátovce–Súdovce–Dudince axis. In comparison, small hillfort locations seem to be the least influenced by the access to the south–north route. Further analysis is needed in the future to determine whether other routes bound in different directions might affect the location of the hillforts or whether mobility-unrelated issues are at play in those cases. When factoring in the 2,000 m buffer, nearly all of the large hillforts seem to have been located along the ideal route. Only one-fifth of the hillforts are located within 2,000 m of a presumed or documented major river crossing in the area. However, the highest concentration of hillforts appears to be clustered at the fords on the Váh in Ružomberok and Liptovský Mikuláš, as well as at the crossings of the Slatina and Hron rivers in Zvolen.

![Figure 11: Relation of documented road-related landscape features to the fortifications found at Slovenská Ľupča.](image)

| Table 1: Quantification of the importance of road-related features to hillfort distribution in the landscape |
|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Hillfort size | Total no. | Distance from ideal route | | Distance form river crossing | | Distance from mountain pass | | Distance from raw material source |
| | | 500 m | | 2,000 m | | 2,000 m | | 2,000 m | | 10,000 m |
| No. | % of category | No. | % of category | No. | % of category | No. | % of category | No. | % of category |
| S | 36 | 8 | 22.22 | 21 | 58.35 | 5 | 13.88 | 0 | 0 | 6 | 16.26 |
| M | 50 | 23 | 46 | 33 | 66 | 14 | 28 | 0 | 0 | 9 | 18 |
| L | 10 | 6 | 60 | 9 | 90 | 2 | 20 | 0 | 0 | 3 | 30 |
| XL | 1 | 0 | 0 | 1 | 100 | 0 | 0 | 1 | 100 | 1 | 100 |
| All | 97 | 37 | 38.14 | 64 | 65.97 | 21 | 21.94 | 1 | 1.03 | 19 | 19.58 |

XL hillfort Sitno distance from raw material source counts 100%. The count is, however, irrelevant for Bronze Age from chronological reasons and for Middle Ages from political reasons.
If smaller streams were considered, the ratio would be much higher. It is debatable whether the small stream crossing is of any importance. This might be too unique at any location to generalise; therefore, it has not yet been evaluated. In addition, whilst more than half of the medium-sized hillforts are located within 2,000 m of the major rivers, the ford remains beyond this buffer, which is due to topographical issues in many cases. Only a single hillfort is located within 2,000 m of a mountain pass. From this result, it can indicate that the location of hillforts is not greatly affected by these features.

Observations indicate that large hillforts tend to be located on the nearest path between a major river crossing and an important mountain pass. In some instances, controlling the source of raw minerals might have been the main reason for establishing a hillfort. The spatial analysis also reveals that only 19.58% of the hillforts located in the studied area are located in proximity to raw mineral resources. Whilst proximity in this study is defined as a perimeter 10 km from a known source of raw materials exploited during the selected timeframe, this distance is assumed to be the limit of reaching the exploitation site from the hillfort in the mountainous terrain and returning in one day via the transportation means available during the targeted timeframe. The timeframe was set upon hiking trails signs in the observed area (they usually feature time costs from the current point to the next on their signs) and own experience of the author. This is based on the assumption that control over a certain point could be described as possibility of an immediate reaction to any special situation (e.g., 3 hours for the situation message coming in, 4 hours for the reaction party to prepare and arrive at the situation site, while the reaction party needs to stay in physical condition to react after the movement). However, the largest hillfort in the area, Mt. Sitno in Ilija, is an important example that indicates the ability to control resources is not the main factor influencing the location of a

### Table 2: Average, maximum, and minimum distance of hillforts from ideal route model for each hillfort size category

<table>
<thead>
<tr>
<th>Hillfort size</th>
<th>Average distance from ideal route (m)</th>
<th>Max. distance from ideal route (m)</th>
<th>Min. distance from ideal route (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>1,572</td>
<td>4,357</td>
<td>72</td>
</tr>
<tr>
<td>M</td>
<td>1,376</td>
<td>7,150</td>
<td>0</td>
</tr>
<tr>
<td>L</td>
<td>950</td>
<td>3,684</td>
<td>14</td>
</tr>
<tr>
<td>XL</td>
<td>876</td>
<td>876</td>
<td>876</td>
</tr>
</tbody>
</table>

(Figure 10).
hillfort. The hillfort is located approximately 1,900 m to the east of the Krížna Pass, which crosses the ledge of the Štúavnické Mountain caldera, whilst another recorded mountain crossing is located at Štúience just 900 m to the east of the hillfort gate. The site is located within 10 km of the silver mines of Banská Štiavnica. However, the proximity to the mining area is relevant only to the medieval phase of the site as silver mining activities are not recorded in the area before the Middle Ages. During Middle Ages, the relevance is contested by the existence of the Glanzenberg hillfort (a fortified town with a castle) in Banská Štiavnica, which is located in the mining fields. No evidence supports silver mining activities in the area during the Bronze Age when the hillfort was first established. However, a Bronze Age hoard found near road remains at Mt. Holík suggests that an important route may have already existed when the hillfort was established (for an account and chronology of the site, see Labuda, 2016; for a 3D model with explanatory notes, see Miňo & Lieskovský, 2020). A similar interpretation for Bronze Age hoards in Poland is suggested by Maciejewski (2017, p. 121). Most contemporary settlements are located at a significant distance from the hillfort. Although there are two settlements 2–3 km away from the hillfort, their capacity to provide long-term sustenance to the highly populated hillfort during this time period is unclear due to poor soil quality and its low population (i.e., low labour power in the settlements). Similar settlements were excavated in Detva (Kvietok, 2016; Pažínová, 2016), Žiar nad Hronom (Malček, 2008), and Kováčová (Kvietok, 2019), which consist of a maximum of three homesteads separated 120–250 m from each other. The settlements that might have provided for the basic dietary needs of the Bronze Age hillfort inhabitants were located within a 15–17 km radius in agriculturally productive environments, i.e., due to the fertility of soils, size of the arable area, and climate, and aided by Bronze Age technologies. This means that the control of important land from an agricultural point of view does not seem to be an important factor in determining the location of a hillfort. The hillfort lies on a mountain of distinct height and shape. These features make it recognisable from a large part of the researched route and even a higher distance to the south. Thus, it is an important landmark which might have been used for orientation. It might be important that even though not settled in the Roman Imperial Period, the mountain is mentioned in Claudiós Ptolemaios’s Germania Magna as ‘Sarmatici’ Mountain (Bolina, Matínek, Čílek, & Šlézar, 2022, p. 59). It is mentioned as the only site from the researched area. As a result, it is likely that the existence of the route is probably the most important factor for the location of this 21 ha hillfort, the economy of which was based on mobility and trade. This is why Mt. Sitno is highlighted as a questionable result in Table 1, where all of the results described earlier are quantified.

Only two shifts in mobility patterns can be observed in the studied area during the chosen timeframe. From the Chalcolithic until LBA, roads relative to western variants of the ideal route that cross the Low Tatras via Hiadel Pass could be observed. However, from the early Iron Age until the end of the Imperial Roman period, the preference shifted eastwards, and the Krížske Pass or another yet undocumented mountain crossing in the vicinity of Mt. Žumbier and Mt. Chopok may have been used. However, both corridors were used in the Middle Ages, although the eastern path shifted further east to the Čertovica Pass.

4 Discussion

The existence of south–north long-distance trade routes dating from at least the Copper Age, if not earlier, is documented in the researched area through written medieval sources and the distribution of raw minerals originating from central Slovakia in the Carpathian Basin and the Vistula River Basin and beyond. Multiple south–north roadways recorded in the area of the raw minerals comprise the physical evidence of this trade, especially when considering the find of malachite copper ore from Špania Dolina–Piesky in one of the hollow ways in Sliač–Sampor (Figure 8, feature 4), which constitutes a full day of travel to the south. The existence of an important long-distance trade route has a developmental impact on settlement structure and on individual settlement units. This is a phenomenon that can be observed even today (Bolina et al., 2022, p. 31). As the main routes in the landscape are not documented in any form before the 18th century in the researched area, studying the impacts of road infrastructure on the establishment of settlements can be challenging. In particular, reconstructing routes by simply linking sites can be a source of
misinterpretation, especially in mountainous regions with complicated topographies. By using a combination of landscape evaluation of possible passage corridors with fragments of recorded paths in the landscape, a more accurate model of prehistoric and historic routes is obtained. A comparison of this model to the recorded archaeological site distributions, together with a consideration of different development-boosting possibilities (e.g., mineral resources occurrence, soil fertility) and cultural, social, and political variables, can help achieve a more accurate view of past strategies.

From the analysis presented, it can be concluded that most of the prominent settlements (defined as hillforts and later as castles) emerged for many reasons, the most important of which was the goal of establishing control over parts of the long-distance trade route (overview on this topic for European South – North routes, e.g., Bolina et al., 2022). The larger and more populated the hillforts, the greater the importance of the location, its features, or the proximity of the road, even at the cost of using prolonged logistic routes for the transport of basic subsistence goods, as illustrated by the hillforts at Mt. Sitno and Moštenica. Of all the hillforts where the proximity to the trade route was considered the main reason for their location, the presence of a pathway through a significant topographic obstacle is also an important factor. The proximity of important major river crossings appears to be of the highest importance when situating a hillfort, while the distance to a mountain pass played a role in the smaller number of sites, with Mt. Sitno as one of the prominent examples in the region. A specific combination of control over a river crossing and a mountain pass can be observed in Low Tatras (Moštenica, Nemecká, Rohačka, etc.). This combination forces the location of the hillfort to higher ground and results in a greater distance from both topographical features. The detection of this phenomenon is possible only through the individual assessment of the sites, which matches neither the criteria set for the proximity to river crossings nor the proximity to mountain passes. In unfortified lowland settlements and small hillforts, the relevance of a route’s proximity seems to be of lesser importance and is highly dependent on the region. The main concentration of settlements clusters around features such as fords or trails along the route. A higher ratio of settlement sites is observed to be dispersed further from the road-related features in the regions with more fertile soil than in those regions with limited agricultural possibilities, where the location of the settlement is almost exclusively linked with the route-related topography (e.g., river crossings, mountain passes, drinking water sources) or raw mineral resources.

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