Mapping the Via Belgica II: Maastricht to Heerlen

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Abstract

It is well established that the Romans introduced vast networks of main roads all throughout their territories to facilitate control of foreign provinces and trade. One of those roads, the so-called Via Belgica, linked the northern territories from modern-day Cologne to Boulogne-sur-mer. Since then, the human landscape has drastically changed, meaning that we do not know the exact path this road followed. Our research aimed to map the Via Belgica between the cities of Heerlen (Coriovallum) and Maastricht (Trajectum ad Mosam). This was done by combining data from earlier excavations with knowledge about Roman road construction techniques and preferences, and applying this knowledge to create a path with GIS. The proposed route would lead from Maastricht northeast to Meersen, then southeast through Houthem and Valkenburg, and then northeast through Klimmen, Voerendaal, and finally straight towards the Roman bathhouse in Heerlen. Comparisons with other Roman roads in the northern provinces of the empire do imply a curvier route than normal, but this is not unusual seeing the uneven topography. Overall, the final route coincides with paths previously theorised using different methods.

Introduction

A territory as vast as Europe could not be ruled from a single political centre, Rome, without a way for colonists, legions, information, or goods, to efficiently reach all corners of the Empire. For the purposes of administration, military supply routes and trade, a vast network of roads was constructed throughout the Roman Imperial domains (Berechman, 2002; Carreras & De Soto, 2013; Rodríguez et al., 2022). This need for communication infrastructure is evident from similar road systems being constructed by other Empires which governed large stretches of land, such as the Incas in Peru (Garrido, 2016) and the various Chinese Dynasties (Baker, 1930). Although it had European precursors, the Roman road system was the first to create a well-connected network covering most of Europe (Xeidakis & Varagouli, 1997). In fact, many roads remained in use long after the fall of the Empire (Jeneson, 2013; Rodríguez et al., 2022), and also served as an example for building roads centuries later. But perhaps the greatest legacy of the Roman network are the settlements (civitates, coloniae, and vici) it allowed to found, many of which currently remain important settlements in Europe (Panhuysen, 2009). In the Netherlands, such a history of settlements is evident only in the southern regions, which formed the northernmost continental territories of the Empire until its fall in the 5th century AD.

After the conquest of Belgic tribes, such as the Eburones, Atuatuci, and Cugerni (Caesar, 1869) by Emperor Augustus Caesar around 50 BC, a main road now known as the Via Belgica was constructed in 20BC by general Marcus Agrippa, then governor of Gaul (Panhuysen, 2009; Jeneson et al., 2020). It crossed latitudinally the provinces of Germania Inferior and Belgica, from the Rhine river to the English Channel at the port of Gesoriacum (Boulogne-Sur-Mer). Between the two important capitals founded along the Via Belgica, Colonia Claudia Ara Agrippinensis (Cologne, Germany) and Atuatuca Tungrorum (Tongeren, Belgium), the road passed through the modern Dutch region of South Limburg at two important locations. A large bridge crossed the river Maas at Trajectum ad Mosam (Maastricht, literally

“Crossing of the Maas”), a small vicus at a day’s march from Coriovallum (Herleen). The latter vicus seemed to be an important site of pottery production where the Via Belgica crossed another road from Augusta Treverorum (Trier), the Via Traiana (Jeneson et al., 2020).

Although the Netherlands is considered a flat and low-lying country, uplift from the Ardennes and fluvial erosion processes lead to the unique valley landscape of Zuid-Limburg (Veldkamp & van den Berg, 1993). Fluvial erosion and deposition processes create the fluvial terraces found in the Maas and Geul valleys, most recently in the Pleistocene epoch (Vandenberghe et al., 1985). In general, the landscape is still considered a tertiary peneplain - a flat landscape shaped by erosion (Fig. 1) (Van Den Broek & Van Der Waals, 1987). Leading to the loess and some tertiary deposits dominating the geography of the landscape (Vos et al., 2020). Generally, the higher elevation found in the region makes for a more stable area than in the west and north of the country (van Lanen et al., 2015). Due to deposition by the rivers from the Ardennes, the terrace slopes consist of fertile loess and calcareous loam soils, with a few instances of boggy areas such as the one found west of Voerendaal (de Vries et al., 2003). The Roman colonists quickly realised that such conditions were particularly favourable to agriculture: by the 2nd century AD, the entire region became an important grain store, as attested by the numerous *villa rusticae* (large farms) excavated between Tongeren and Cologne (Jeneson, 2013; de Groot, 2006; Verhagen & Jeneson, 2012).

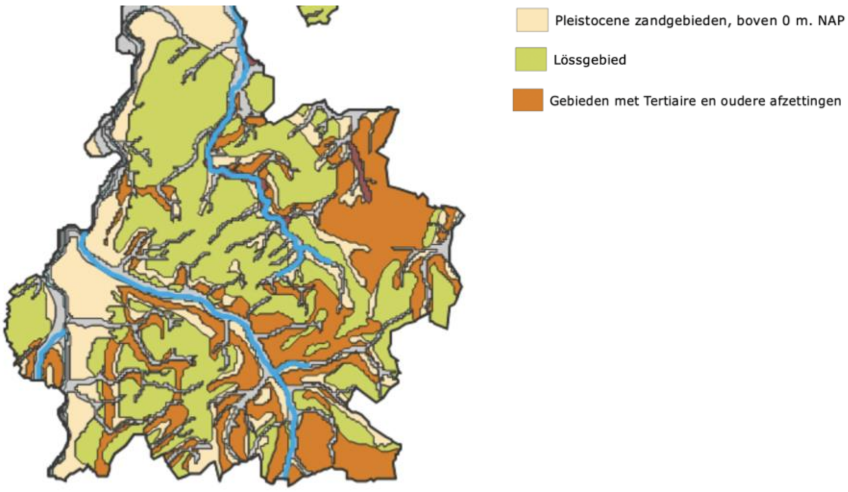

Figure 1: Paleogeography of the Netherlands in 100 A.D. (Rijksdienst voor het Cultureel Erfgoed, n.d.)

Being both the southernmost region of the Netherlands and the northernmost of the Roman Empire, Limburg has been the centre of national archeological interest in Antiquity for almost two centuries (de Groot, 2006). It has helped gather a large body of archaeological evidence, especially concerning Roman *villa rusticae* (de Groot, 2006). Such interest culminated with the 1977 creation of a museum around the oldest stone building in the Netherlands - predating the Coliseum in Rome -, a civil bathhouse founded between 40-70 AD in Coriovallum (Heerlen) (Jeneson et al., 2020). Limburg takes considerable pride in its Roman heritage, which can also be observed today in the numerous road names still holding prefixes, such as steer/stein (stone), alluding to their Roman past (Jeneson, 2013). However, such evidence should be examined with caution as many roads were named with the same prefixes during the Napoleonic era (Renes, 1988). The same goes for so-called “Via Belgica” itineraries, which have been created for tourism purposes without necessarily much evidence to back them up.

Many attempts have been made to reconstruct the actual route of the Via Belgica using a variety of methods, ranging from reconstructions using extant archaeological evidence, active archaeological investigation, or GIS modelling of the most efficient route based on landscape constraints (Demey & Roymans, 2004; Verhagen & Jeneson, 2012). The present study is a follow-up to the January 2023 project ‘Mapping the Via Belgica I: Maastricht to Tongeren’ led by students of the Maastricht Science Programme, where the road section in focus continues from modern-day Maastricht to Heerlen. The aim is to build on previous research by combining a landscape GIS approach and archaeological datasets to reconstruct a potential path for the Via Belgica. Moreover, in their study using solely GIS modelling, Verhagen & Jeneson (2012) have argued that proper modelling requires a clearer idea of constraints on historic transport and construction methods. Only experimental archaeology can establish the importance of factors that determine the chosen path, such as cart speed, maximum slope, and visibility. Hence, the present study also includes a reconstruction of a Roman road-building device, the groma, to get an idea of the accuracy of Roman tools to establish straight paths.

Methods

To construct a possible path for this ancient road, a combination of archaeological and geomorphological data was compiled to be mapped on ArcGIS. The most likely route resulting from this analysis was then walked to assess it from a phenomenological perspective. Finally, Roman road building in a hilly landscape was approached by assembling a groma and assessing its precision in the hilly landscape of St Pietersberg, Maastricht.

Modelling the route with ArcGIS

Archaeological data collection

Archaeological data points were retrieved from the ArcHis3 database of the Cultural Heritage Agency of the Netherlands (Rijksdienst voor het Cultureel Erfgoed, n.d.), an initiative of the government to protect Dutch cultural heritage. It has been recording all Dutch archaeological activities since 1995, their location and other information such as collection date, excavation method, estimated date of origin, etc. In addition, it has recorded all archaeological activities led by the ‘Rijksdienst' since its foundation in 1948; since most activities in the Netherlands have actually been led by the ‘Rijksdienst', ArcHis3 is a reliable source for all findings following this date. However, although it also includes important excavations preceding 1948, it may lack a substantial amount of such older findings. This is shown by K. Jeneson’s research on the settlements surrounding the Via Belgica (2013), which cross-referenced the ArcHis2 database with evidence from museums, archives, and archaeological council reports in Limburg to enrich the dataset with what amounted to half of the original Archis2 evidence. Unfortunately, this dataset - which included funerary and road evidence - is not available to the public and could not be used in the current study.

All relevant data points were obtained using a set of three filters on the ArchHis3 search engine. The selected locations were the municipalities of Maastricht, Valkenburg, Voorendael, and Heerlen, and the appropriate era was selected by using the search term “Roman”. Using these spatial and temporal filters, two separate searches were made in the type categories “Road, (un)paved” and “Tomb (section)” which respectively compiled 60 and 41 records. Each entry’s “RD/NAP Amersfoort RD New system” coordinates were converted into “GPS (WGS84)” using “The World Coordinate Converter” (Rozon, n.d.) and uploaded to an ArcGIS map. The municipality, era, and additional information regarding the finding such as number and types of burial grounds were also retrieved from each point’s metadata on Archis3. Data points from the west bank of the Maastricht municipality and the east and south of the Herleen municipality were not retained for analysis, leading to a total of 41 archeological sites on or around the via Belgica.

Figure 2: Map of all 41 archeological sites on or around the via Belgica, including funerary, road and settlement evidence.

<u>Geomorphological data collection</u>

The soil map of The Netherlands, created by de Vries et al. (2003), provides data for all soil types as classified by Bakker and Schelling (1989) at a depth of 1.20m. The map was downloaded as a feature layer from the ESRI Netherlands ArcGIS database to show all soil layers on ArcGIS.

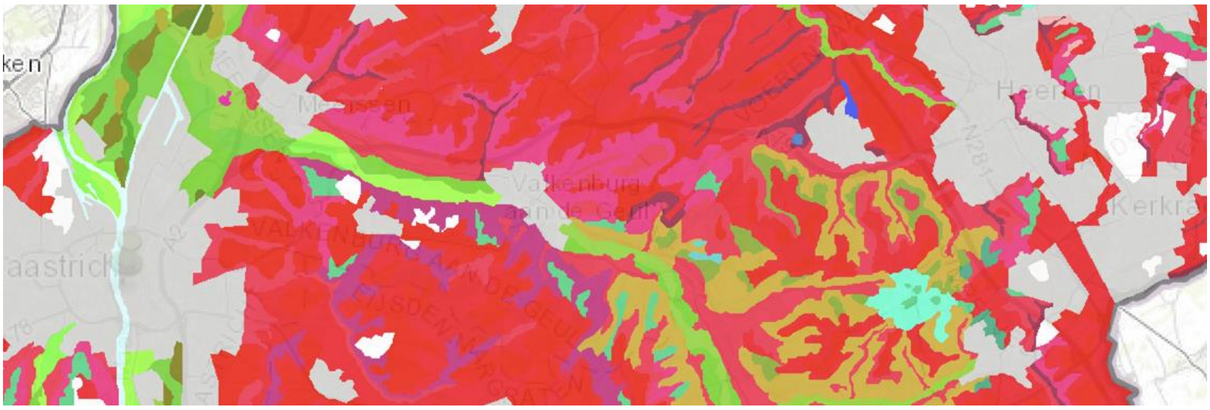

Figure 3: Soil map of the Zuid-Limburg. Legend: Grey: Construction ground, Red: Silty Loam, Pink: Loess, Light Green: Calcareous Sand Soil, Dark Green: Chalkless Polder Soils

The AHN-2 model (*Actueel Hoogtebestand Nederland, n.d.),* is an accurate elevation model of the Netherlands with a resolution of 1 square metre. Laserimetry from aircraft and helicopters was used to create such a detailed model. It shows how Limburg sits on a considerably higher plane than the rest of the Netherlands, at about 100m compared to the near sea level of the rest of the nation. The ANH-2 model was uploaded via ArcGIS and is provided by ESRI Nederland.

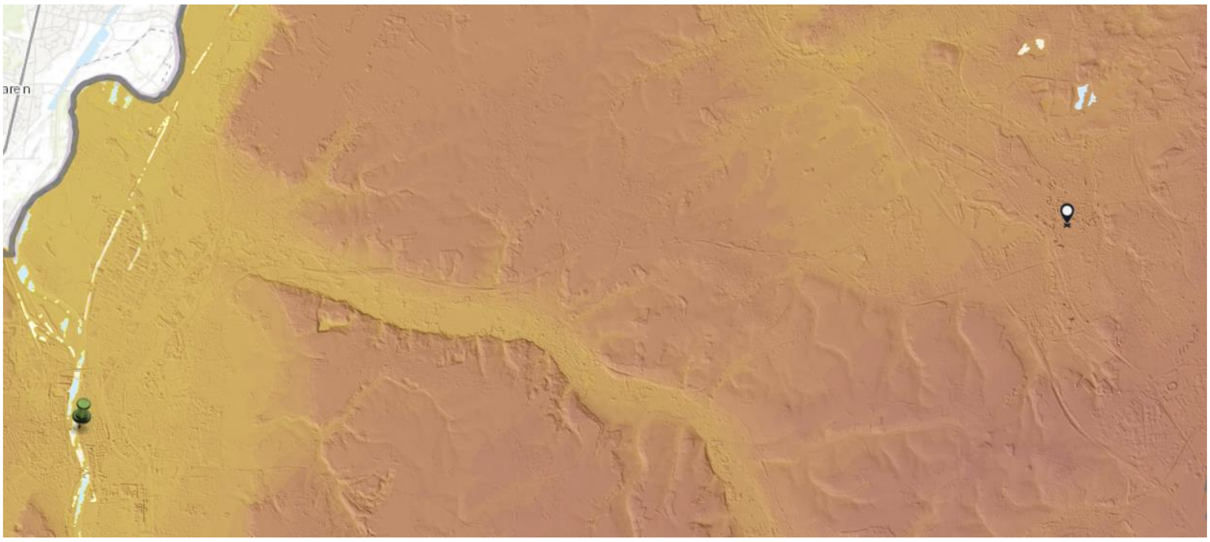

Figure 4: Elevation Profile of Zuid-Limburg, Maastricht and Heerlen shown as pins: Key - Light orange: low elevation, dark orange: high elevation

ESRI provides a multi-resolution world elevation map with analysis features such as slope, hillshade and aspect. The "Terrain: Slope Map" is the one employed to create an accurate visualisation of the slope found across the Zuid-Limburg area.

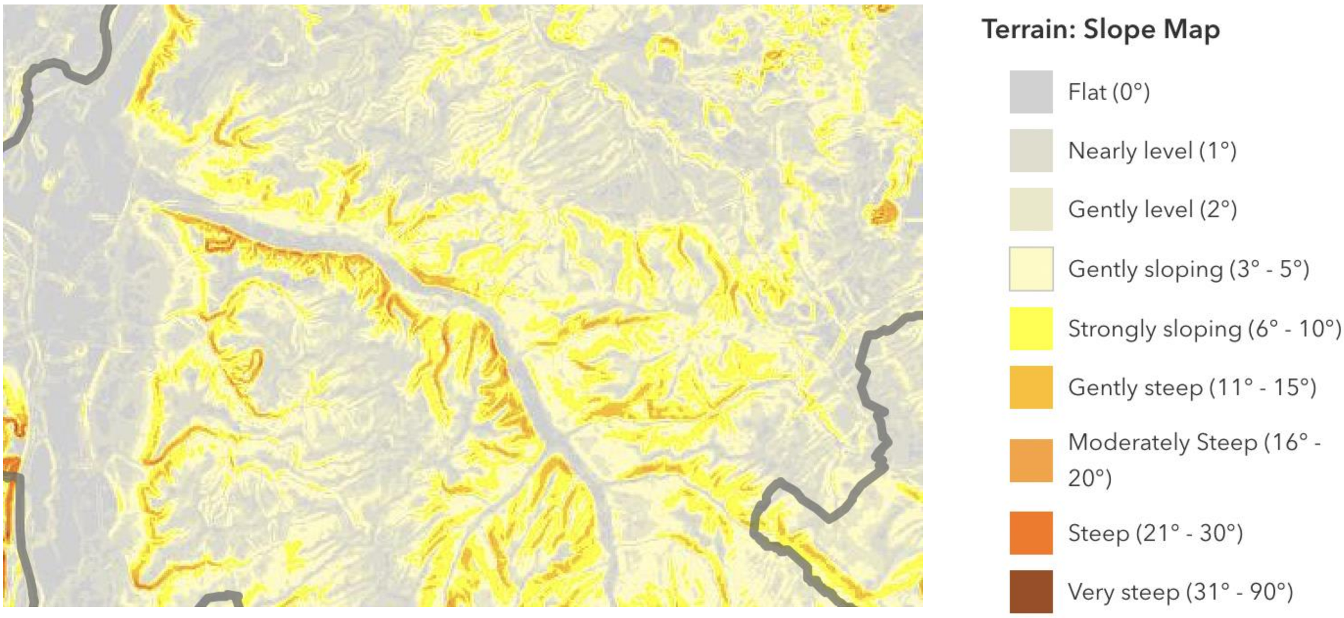

Figure 5: Slope Map between Maastricht and Heerlen

Assessing the landscape and creating the route

When building roads, the Romans showed clear preferences for straight lines (Plutarch, 1921), probably to reduce building costs and time (Margary, 1967; Verhagen & Jeneson, 2012). In uneven surfaces where the straight line is not necessarily possible, roads with a military purpose were preferably built on high ground to have a view of the surroundings (Brulet, 2017). With these premises in mind, a pseudo-network friction analysis was conducted for the landscape between Heerlen and Maastricht. It aimed to predict lowest cost areas for the construction of a Roman road based on the data and maps gathered. A network friction analysis assigns friction values to landscapes based on their soil composition, elevation and slope to identify and classify these areas. For example a steep slope would require more time and energy to cross than a flat one, or peat soil is more difficult to traverse and build a road on than a loam or silt substrate (Verhagen & Jeneson, 2012).

Initially the “Plan Routes” function in ArcGIS was employed to create a walking route along the existing road network from Maastricht to Heerlen. The landscape data was then mapped onto ArcGIS to identify areas of low and high network friction.

The soil profile of zuid-Limburg near the proposed route was ranked by accessibility with “accessible” and “inaccessible”. As most of the soil profile was of silty loam, loess and some calcareous sands, only one area was marked as inaccessible; the peat-bog area just west of Voerendaal. A similar ranking was conducted with the slope terrain, it is accepted that anything above an 8 degree slope was considered too steep for reliable travel with ox or horse-drawn carts (Carreras, & De Soto, 2013) and thus any terrain with such inclines was labelled as inaccessible. Inclines of 4-8 degrees were deemed moderately accessible and anything below 4 degrees was considered accessible.

The soil (Fig. 3) and slope (Fig. 5) maps were overlaid on top of each other and any areas with an inaccessible soil or slope was considered as high network friction. Whereas, the moderate and accessible areas were considered as low network friction and as possible areas for the roman road.

Areas of high network friction were discarded from the potential path by creating polygon barrier layers. The “Plan Routes” function was again used to create a route with inaccessible areas. This created a general route outline. Next, the archeological sites were added to the map (Fig.2) . Many points were either too far South or North to be considered part of the route and others were past the start and end points set in Maastricht and Heerlen (Sint Servaasbrug and Thermenmuseum respectively). These were therefore excluded from the intermediate stops. Finally, a route was created that incorporated the landscape barrier layers as well as the archeological site intermediate stops. If two or more archeological sites create splits or equally viable routes, the straighter path was selected. Furthermore, some sections of the route did not follow straight lines due to current road networks following different paths, such as by the train crossing in Maastricht, and through a park in Meersen. A straight line was drawn between those points as can be seen in red in the maps (Fig. 14).

Viewshed analysis in ArcGIS

Viewshed analyses are useful tools in Archeological research and can be employed in many ways such as reconstructing old roads, identifying waypoints between two areas, or even assessing locations' security, and confirmation of cultural identity (van Leusen, 1999). Multiple viewsheds were created in ArcGIS, along the proposed route in Voerendaal, Klimmen, Valkenburg and the start and end points, all with a visible range of 20 km at an observer height of 1.75m. In addition at the location of the two possible watchtowers in Klimmen and the Goudsberg, the observer height was increased to 10m in addition to the 1.75m viewsheds, to simulate the height of view from a watchtower.

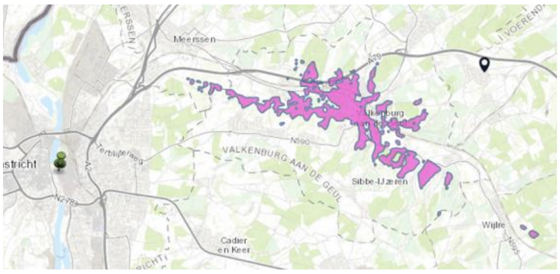

Figure 6: Viewshed from Valkenburg

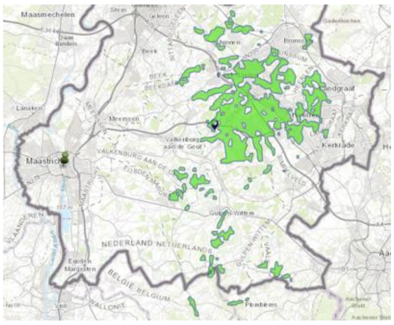

Figure 7: Viewshed from Klimmen

Figure 8: Viewshed from the Goudsberg

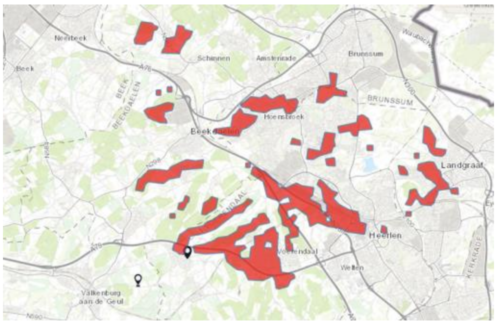

Figure 9: Viewshed from Voerendaal

Reconstruction of a Roman surveying tool to assess potential deviation from a straight path

In addition to planning out the route using ArcGIS and phenomenological observation, a Roman surveying device known as a groma was reconstructed. It is particularly useful to plan straight lines through uneven landscapes (Adam, 1982). A Roman groma is typically made up of three parts: a wooden shaft reinforced with metal - just wood in our case - known as a *ferramentum*, a wooden cross lying on a pivot, identified as the *groma* proper, and cords, *nerviae*, were suspended from each of the 4 arms on the cross. At the other ends of the cords were bronze weights known as *pondera* (Kelsey, 1926). Our reconstruction (Fig. 10) was not as detailed or intricate as the typical groma, which would weigh in at around 16 kg, but obeyed the same working principle and acted as an accurate reconstruction in terms of practicality. The groma could be dismantled and reassembled with ease, meaning it would not be much of a burden for the Roman surveyors.

To use the groma, two of the *nerviae* are lined up together with the city of which the road is planned to originate from. The three points - two cords and the start location - effectively form a straight line (Fig. 11) . It is used to direct an individual situated opposite from the start relative to the groma, typically in a place lacking a proper view on the start location. To this effect, both the groma and second individual should be standing at locations with a wide field of view. The individual manipulating the groma would then direct the second individual to move until he is in line with the line formed from the cords and the start location (Fig. 12) . This location would then be marked with a stick or beacon, and the process would be repeated using this beacon as the start location for the individual manipulating the groma, allowing for the continuation of a straight road.

Fig. 10: Aligning the nerviae with the start location

Fig. 12: Using a coloured cloth to signal

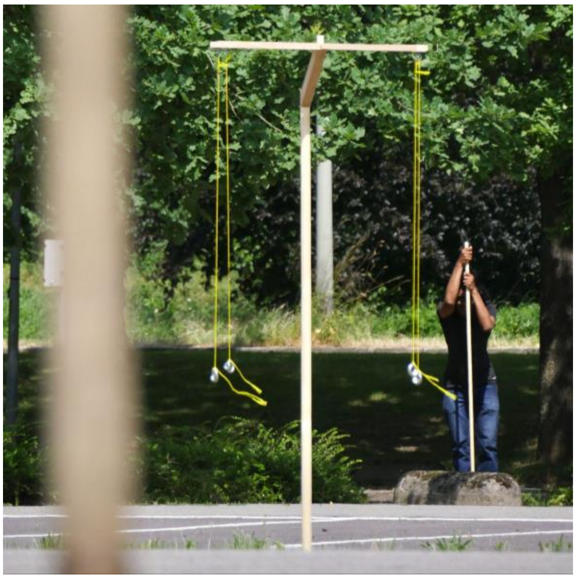

Fig. 11: Two sticks aligned with the nerviae

Fig. 13: Nerviae cords aligned with the surveyor

To test out our model, the groma was set up on top of the tallest point in Maastricht at Sint Pietersberg. From here, the Onze Lieve church was noted as the start point for a mimic road. Meanwhile, another member of our group was sent to stand a few hundred metres in the opposite direction with a wooden marker. The manipulators of the groma would then use a red flag to direct the one with the marker to stand in line with the two cords and the coordinates of the groma, wooden placeholder and church were taken down (Fig. 13).

Results

The route created with ArcGIS

On June 28th, 2023, the most likely route as created with ArcGIS was walked to assess the travel time and distance, slopes, width of the views, and feasibility of river crossings. The route is 24.88 km and took approximately 9 hours to walk with a lunch break.

The route begins at the famous Servaasbrug where the Roman bridge would have been located (Jeneson, 2013). The road then turns north toward Meersen. Just before Meersen the route crosses the two narrow and shallow splits of the river Geul, after which the road turns east. The route continued at a slight incline up the northern slopes of the Geul valley until the city of Valkenburg.

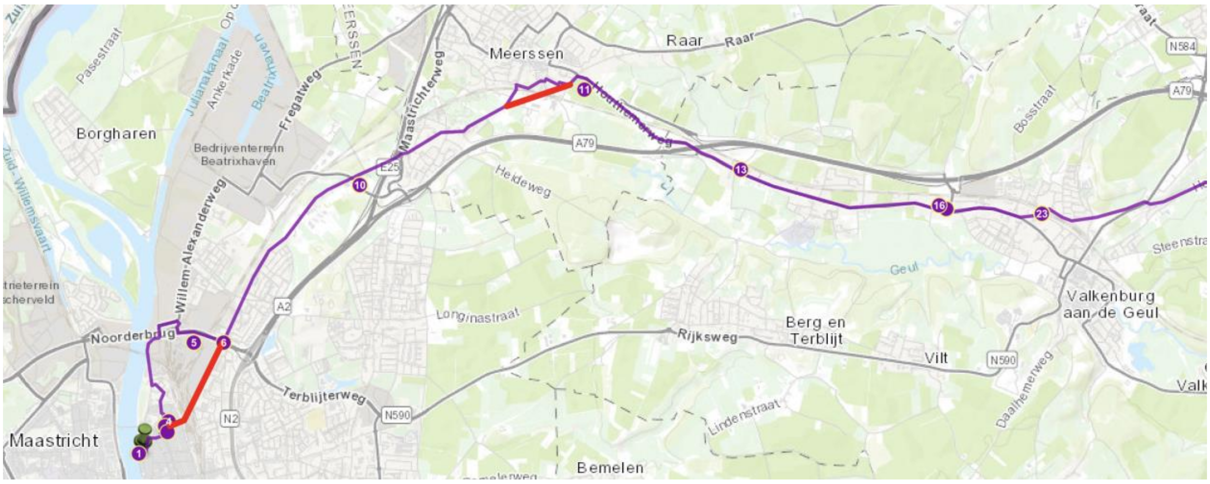

Figure 14: Route from Maastricht to Valkenburg, The purple line indicates the route created via the "Plan Routes" function. The red lines indicate the alterations to the route made due to the limitations of today's road networks.

The stretch of the route following Valkenburg leaves the Geul valley, which turns south, to climb at a 5° incline toward Klimmen, making it the steepest section of the route, which had overall a mild uphill gradient. Finally, the route descends from Klimmen and passes through Voerendaal, avoiding an area covered with peat bog soil. Continuing in a straight line, the road ends at the remains of the Roman bathhouse in the Thermenmuseum of Heerlen.

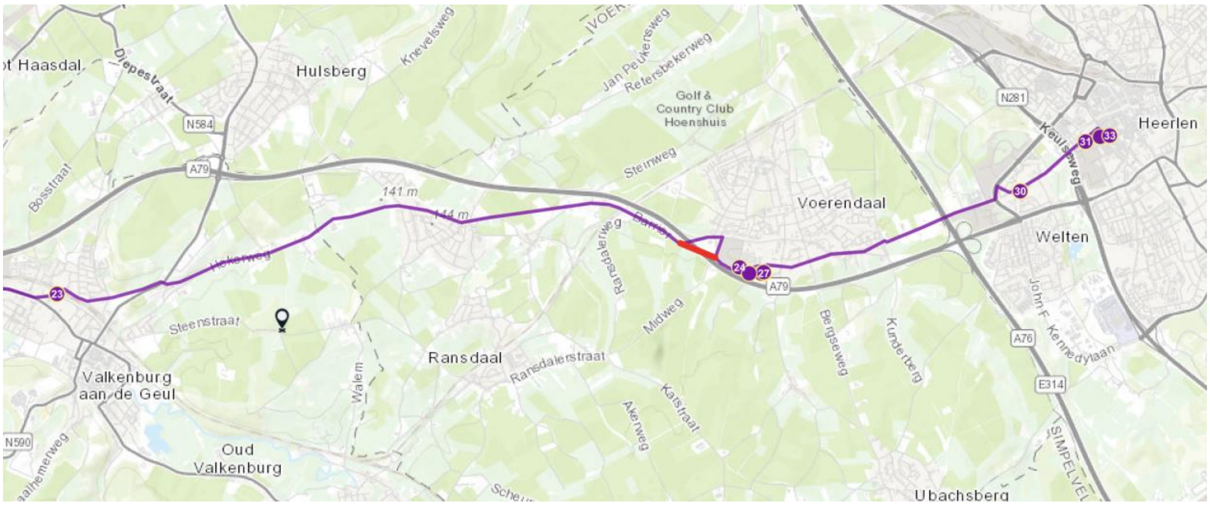

Figure 15: Route from Valkenburg to Heerlen. The two pins represent the potential watchtowers at the Goudsberg and the Klimmen church.

Assessment of the precision of the groma

South Limburg being a region of valleys and hills, the groma would have likely been used to plan straight segments of the Via Belgica. The reconstructed prototype was used to evaluate how accurately Romans could build a straight path between Maastricht and Herleen (Fig. 10-13).

After testing the groma, angle error values were calculated to represent the deviation from a straight line. The theoretical straight line was calculated using the GPS coordinates of the start location and the groma, while the practically determined line was calculated by linking the coordinates of the start location with the position of the wooden stick used in place of a beacon. The angle measured between the two lines can simply then be calculated by taking any two points on either line created from the point of the groma, provided the two points are perpendicular to either of the lines. The distances from the groma to these points are measured, with the shorter distance being divided by the longer one. Once that value is taken, to find the angle of deviation, we simply put this value in an inverse cosine function which was found to be 1.83°.

Using this error value of 1.83°, we can crudely simulate the deviation of a straight path over 22 kilometres, in order to test if such a deviation would be detrimental over a large distance. The simple multiplication of sin(1.83°) with the true straight line distance of 22 km yielded a deviation of about 700 metres.

Discussion

Evaluating the GIS route

As mentioned in the introduction, the Via Belgica has become a popular tourist attraction: the tour guide to the "Via Belgica" (Brandts et al., 2021) proposes routes supposed to coincide with the Roman road. Some propositions show interesting options, but also many rather ridiculous suggestions, effectively making them unreasonable approximations of the actual road. For instance, the proposed stretch from Maastricht to Meersen is reasonable although it follows a path lining the river rather than a straighter path following archeological sites (Demey & Roymans, 2004). On the other hand, the proposed stretch between Meersen and Valkenburg suggests a heavily winding and indirect route, uncharacteristic of Roman roads. Moreover, the guide fully disregards important archaeological evidence: for instance, it completely bypasses the Thermenmuseum in Heerlen, despite excavations showing it is where the Via Belgica crossed the Via Traiana (Jeneson et al., 2020). With these observations in mind, it is safe to assume the popular versions of the Via Belgica hold little accuracy. Hence, we aimed to reconstruct a plausible route using both archaeological evidence and knowledge of Roman road-building habits.

As previously mentioned, the stretch of the Via Belgica from Maastricht to Heerlen is more curvy than usual Roman roads (Jeneson, 2013). According to our analysis, turning North instead of East at Maastricht was done to avoid a steep plateau, and rather pass through the fertile Geul valley. Archaeological evidence for this curve exists in the numerous tomb remains found on the east banks of Maastricht and along the Meersenerweg. Remains of a roman *villa rustica* have also been found in a field as the road turned back east after Meersen. This is in line with Jeneson's analysis (2013), who also argued for a northward turn after crossing the Maas.

Burial grounds are considered good indicators for the location of a main road (Jeneson, 2013). In Antiquity, they would be laid outside settlements for sanitary reasons, but close to the main roads to facilitate their access (Robinson, 1975) . Burial remains were indeed found lining a Via Belgica section near the Thermenmuseum in Heerlen (Jeneson, 2013). This is corroborated by the fact that all the funerary evidence between Maatricht and Heerlen that could be dated were found to be from the middle Roman era, which succeeds to the estimated building period of the Via Belgica (Panhuysen, 2009; Jeneson et al., 2020). Nevertheless, many funerary excavations remain undated beyond the generic "Roman era", making them a less reliable indicator for the presence of a main road.

Funerary remains were found along the Gueul valley up until Valkenburg. The valley's gentle northern slopes seemed to be particularly fertile, as attested by the numerous *villa rusticae* remains that were excavated (de Groot, 2006; Jeneson, 2013). However, a notorious lack of archeological evidence remains in the section between Valkenburg and Voorendael apart from two potential roman watchtowers at Goudsberg and Klimmen, today a church (Jeneson, 2013; Verhagen & Jeneson, 2012). This uncertain section is the subject of Verhagen & Jeneson (2012), which identified three possible routes using GIS. According to our network friction analysis, some sections were too steep to pass by the Goudsberg watchtower, and the road displayed in Fig. 15 followed a less costly surface. Once again, this raises the necessity of experimental archaeology to determine the exact maximum incline Roman carts could climb.

Continuing the road into Voerendaal, multiple sites were discovered on the 'Oude Midweg' street, including Roman road remains believed to be part of the Via Belgica (Jeneson, 2013) and funerary evidence. The road passes through more funerary and settlement sites in a neat, straight line, before ending at the remains of the Roman bathhouse in the Thermenmuseum of Heerlen, making this section quite certain.

A viewshed analysis was also used to better elucidate this section of the road. It provided varied results but showed Klimmen, situated at the top of a hill, provided a great outlook over the entire eastern portion of the route, although the view did not cover Valkenburg and any of the Geul (Fig.7). The 10m height indicated little significant change in the viewshed. Alternatively, the route proposed by Verhagen & Jeneson (2012) passes through the Goudsberg and places a roman watchtower there. The viewshed from this area indicated a view into the Geul valley and could be seen from Valkenburg (Fig. 8). If increased to 10m height the viewshed also extends to Voerendaal and Heerlen. This supports the alternate route through the Goudsberg as higher elevation and a better viewshed were maintained. Nonetheless, a similar viewshed was created on the western side of Klimmen, also providing support for this route. Possibly the route the Romans took was influenced by seeing into the flat Geul valley from Klimmen and believed it to be a viable area for a route towards Maastricht. Valkenburg, situated in the low lying Geul valley has a small viewshed spanning most of the western Geul valley but does not reach Meersen (Fig. 6), however the overwhelming landscape and archeological evidence within the valley overrules the unusually small viewshed, a characteristic Roman roads did not favour. Viewsheds created for Heerlen and Maastricht both easily reached the nearby sites, and confirm the placement of the route within the landscape.

Evaluating the route proposed route with an observational approach

The road was walked to assess potential issues the Romans may have encountered while building the road. One of these was the crossing of the river Geul, which was noted to be no larger than a few metres in width. Accounting for the larger sediment deposits in the river due to the extensive deforestation taking place at the time, leading to larger mass flow in the river, the obstacle would have been small to cross. No evidence remains of a Roman bridge over the river, but the small width and very shallow water makes it a very likely spot for crossing with a simple ford, similarly to the Sinselbeek river west of Maastricht (Jeneson, 2013). A similar situation is true for the Geleenbeek, another stream just East of the modern day Heerlen city centre, which is of such a trivial width, smaller than the river Geul, that no significant construction was needed to cross it (Waterschap Roer en Overmaas, 2000). Judging by the low cost associated with crossing the Geul, it is safe to assume the Romans would not have faced any difficulties, leading to why there are no historical accounts of a somewhat inconsequential obstacle (Herzog, 2010). Indeed, the only mention of a river crossing in the Civitas was the bridge at Trajectum Ad Mosae.

While the modern walking route consisted of asphalt road and a short stretch of gravel, the soil and geomorphology could still be analysed via ArcGIS. Given that only one area - the peat bog by Voerendaal - near the route was deemed inaccessible, and it is found close to remnants of road sites (Middle Roman Period) and a roman *villa rustica* (Middle Roman Period), it is likely that the Romans encountered the area while planning and building the road and thus deliberately avoided it as the proposed route suggests.

Many of the archeological data points are featured exactly on the proposed route, mainly consisting of road and funerary evidence (Fig. 14-15). Some settlement evidence is also found nearby the road such as the *villa rustica* on the outskirts of Meersen, although most are located deeper in the country. Villas were usually large farm complexes with multiple acres of fields and were commonly 5 km away from a main road (Jeneson, 2013). Only on the Coriovallum-Iuliacum (Jülich) section of the Via Belgica were road-side settlements found (Jeneson, 2013).

One site was found further away from the proposed route, a road segment believed to be part of the via Belgica, cremation sites and settlement (1st and 2nd century AD) directly south of Rothem. The original path on Fig. 14 rather passed by a funerary site on a similar longitude but closer to Maastricht (75-150 AD), shown in purple in Fig.16. Given the similar time periods, it is likely that the funerary site belonged to a network of villas, roads and settlements along the main route of the via Belgica, which would rather follow the straight light blue line shown in Fig. 16.

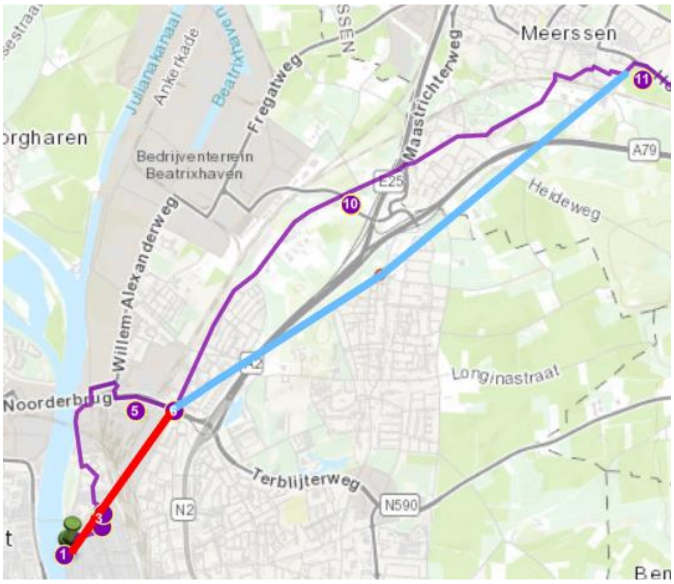

Figure 16: The blue line indicates the route passing through the road and settlement remains, whereas the purple line passes through the funerary site north.

Overall, the modern-day route took approximately 9 hours to walk, which very much fits into the Roman geographic ideology of having two major settlements directly connected within a day's travel (Thermenmuseum, 2023). A day’s travel for most trade wagons, typically pulled by mules, would be around 16-22 kilometres and with no major slope changes on the route (Cèsar Carreras & Pau De Soto, 2013).

Given that the estimated deviation caused by a groma from a straight path is only 700m, the deviated point would likely still lie within the vicus of destination, Coriovallum, and the deviation could easily be corrected by slightly changing the direction of the road in the last few kilometres with the vicus in sight. The major cause for deviation is thought to be the wind in the open field leading to the *nerviae* on the groma to deviate slightly from the original straight line that might have been first noted. Another cause for error could simply be down to the thickness of the *nerviae* that was used, as even the small thickness of the cord will extend a deviation over a large distance, as evidenced by the deviation from the line even over a small angle. The Roman groma would have certainly been more expertly built than our prototype to minimise deviation (Kelsey, 1926). In any case, such a small deviation over such a distance for a device of that era - not accounting for human errors obtained on our part from a lack of experience - is a testament to the Roman importance and mastery of road-building.

The construction of the Via Belgica

There is a broad structure to the most important Roman roads, which were properly built infrastructures rather than simply traced in the landscape (Garilli et al., 2017). The soil would first be loosened, and then dug out until some sort of stable ground or hard rock would be found (Rodríguez et al., 2022). This ground would be levelled and ready to receive a layer of lime mortar to further smooth the base of the road (Garilli et al., 2017). If the lime mortar was not available, sand could also be used (Berechman, 2002). After these preparing steps, the first base layer (*statumen*) of large stones cemented together with lime mortar or clay would be placed (Berechman, 2002; Xeidakis & Varagouli, 1997). Next, the second base layer (*rudus*) would consist of small stones mixed in with lime mortar or clay and sand that were thrown into the hole and compacted (Berechman, 2002; Garilli et al., 2017). The last layer (*nucleus*) would be composed of a concrete made out of gravel or thick sand mixed with lime, which would then be poured and compacted with a roller (Garilli et al., 2017). This layer would be higher in the centre and lower on the sides to facilitate drainage of water (Berechman, 2002; Xeidakis & Varagouli, 1997). Oxen-pulled carts are thought to be very impractical on damp ground, which justifies the compact and curved nature of the roads. Some roads would also have side stones along the road (*crepidines*), and a paving of large igneous stones (*summacrusta*) (Berechman, 2002; Garilli et al., 2017; Plutarch, 1921; Xeidakis & Varagouli, 1997). In some instances, Roman roads were not constructed from scratch but built over a pre-existing road to reduce expenses. This may be true for the Via Belgica, built over roads used by Germanic tribes in the area, with a section of the Roman road having been found to be built over a pre-existing paved road (Panhuysen, 2010).

Even though this general architecture is found for many Roman main roads across Europe, local differences in the materials, topography and climate played a major role in determining how the roads were built (Garilli et al., 2017; Rodríguez et al., 2022; Xeidakis & Varagouli, 1997). This is mainly due to the fact that, on the contrary to many buildings like the baths in Coriovallum, Romans used local materials to build their roads (Jeneson et al., 2020; Xeidakis & Varagouli, 1997). Only once built could they allow the transport of heavy materials for other infrastructures. To better examine the section of the Via Belgica in focus in this study, it was compared to the well-studied Via Appia in Italy.

Italy holds a diversity of landscapes, including hills, rugged mountains, marshes, and exposed rocky terrains (Corti et al., 2013). Despite uneven terrain, the Via Appia managed to be built straight while avoiding most of the mountains and hills present. Only the Alban Hills and the Pontine Marshes (swampy terrain) were avoided, forcing a clear detour (Berechman, 2002). As for the layering of the Via Appia, it showed to have all of the aforementioned layers, containing lime mortar in the middle layers and igneous stone paving as the top layer (Adam, 2005). This makes it a *via silice strata*, the most carefully built roads (Garilli et al., 2017).

On the other hand, Limburg is a relatively flatter landscape than the extreme aforementioned regions, but not a flat plain either. The Romans therefore did not need to avoid the entire region, but had to deal with localised uneven terrain in order to build roads with minimal slopes. Hence, to avoid the steep slope east of Trajectum ad Mosam, the Roman road seemed to turn North then East into the Geul valley, although the destination of Coriovallum was a clear East. In addition, the Via Belgica did not seem to follow the layering of materials typical of other Roman roads (Verhagen & Jeneson, 2012). Thanks to a climate more favourable to vegetation than the Mediterranean climate, South Limburg has very few exposed rocky surfaces. Hence, the Via Belgica shows no use of slabs of stone like on the Via Appia, especially since paving was an exception to the norm of gravel roads (Procopius. & Dewing, H. B., 1914). Moreover, the region's rivers would have not been contained before colonisation, meaning that clay, gravel and sand that had been deposited on the banks were readily available (Rijkswaterstaat, 2014). Since then, most of these depositions have been quarried, and are not visible in the landscape anymore. But these were the materials used to build the different layers of the Via Belgica (Fig. 17), with gravel compacted by clay used as the top material (Fig. 18), when the talus was rather used to facilitate drainage (Verhagen & Jeneson, 2012; Xeidakis & Varagouli, 1997). This makes the Via Belgica a *via glarea*, a level above the *viae terrenae* (dirt roads) and below the *viae silice stratae* in the hierarchy of roads (Garilli et al., 2017).

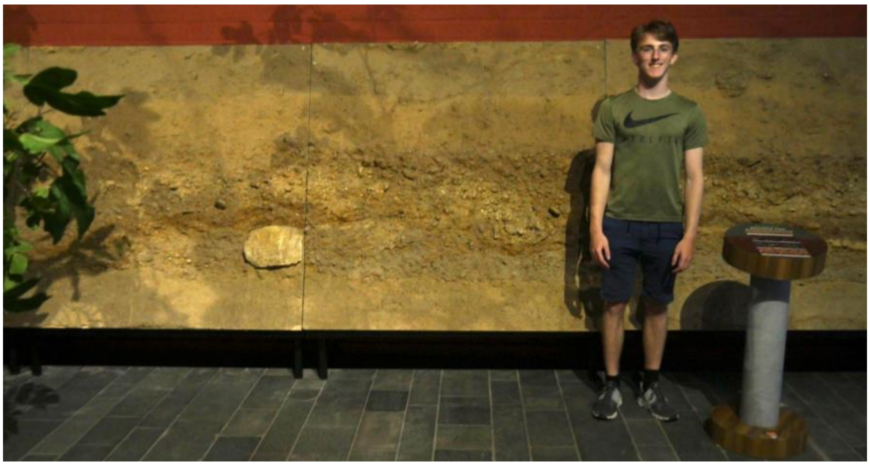

Figure 17: Cross section mould of the Via Belgica displayed at the Thermenmuseum, Heerlen

Figure 18: Reconstruction of the Roman road near Houthem

Conclusion

Some aspects of the assessed path for the Via Belgica road remain assumptions and speculation. Still, through knowledge of Roman infrastructural practices and local geography, estimates were made with varying degrees of accuracy, with some sections relatively certain when others more speculative. Due to topographic constraints on this stretch of the Via Belgica, the Romans would have had to make trade-offs between a road as straight as possible and a road with the least incline. In such a terrain they would have likely used a groma, which was tested and shown to be an accurate method of surveying. Though little can be said with absolute certainty, this paper presented a highly plausible route constructed with GIS through considerations of local archeological finds, local topography and an approximation of Roman decision making when faced with said topography. More experimental archaeology should be done to evaluate the true constraints placed on Roman travel, alongside archaeological surveys on the stretches where the road has the least amount of evidence.

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Appendix

Link to ArcGIS webmap
https://arcg.is/1vbeav1

Group Contributions

Henri: ArcGIS modelling, Introduction (Landscape section), Figures, Methods (ArcGIS), Results (Route), Discussion (Evaluating the GIS route, Viewshed and Archeological sites), Groma Calculations, Data Collection
Tom: Abstract, Discussion (Evaluating the GIS route), Local knowledge
Pratik: Introduction, Methods (Groma), Discussion (Groma, Observed route & Construction), Results (Groma)
Emile: Data Collection, Introduction, Methods (Data Collection, Groma), Discussion, Photos
Nina: Introduction, Discussion (The construction of the Via Belgica)
Tacio: Groma Construction, Discussion (Evaluating the GIS route), Conclusion