

Towards Identifying the Course of a Route Mentioned in 1065

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According to a historical document dating back to 1065 AD, the medieval road known as *strata Coloniensis* connected the monastery of Essen-Werden with Cologne in Germany. Several alternative hypotheses concerning the course of this route were published, they only agree on a fairly small section south of Essen-Werden. The aim of the paper is to identify the most probable course of the medieval road between Essen-Werden and the river Düsseldorf. In their arguments, the supporters of two hypotheses refer to historical maps. After outlining the hypotheses, the paper discusses these historical maps and additional earlier maps, several of them are available in online repositories. For each of the early maps considered, the roads or paths depicted were digitized, mostly on the basis of place names and water courses that could be found both on the old and a more recent map. The results allow assessing the accuracy of the maps and investigating the continuity of the roads. Visualization of high resolution elevation data and aerial images were applied to identify old road sections in some areas. However, these approaches are limited by substantial modern landscape modifications and a large proportion of built-up areas. Due to major changes of the relief, reliable least-cost path calculations to reconstruct the old route should not be based on modern digital elevation data. But it is still possible to estimate the effort of using an old road section by cost computations based on modern topographic data. A comparison of the different route alternatives is presented using these estimations.

Key words:

Geographical information systems, web map services, historical maps, online repositories.

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INTRODUCTION

According to a historical document dating back to 1065 AD, the medieval road known as *strata Coloniensis* connected the monastery of Essen-Werden with Cologne in Germany [Lacomblet 1840, p. 155, No. 205]. According to the text of the document, the rivers Rhine and Ruhr together with this road delimited a triangle. Two of the vertices of this triangle are defined in the document: (1) the location where the Ruhr joins the Rhine and (2) the Ruhr bridge in Essen-Werden. The third vertex is the place where the road traversed the water course known as Düsseldorf (Fig. 1). The main aim of this paper is to investigate the plausibility of several alternative hypotheses concerning the course of this route between Essen-Werden and the Düsseldorf by applying GIS methodology.

Essen-Werden, the starting point of the *strata Coloniensis*, is situated near a crossing of the Ruhr River used by important trade routes in early medieval times [Nicke 2001, pp. 186-187]. Saint Ludger chose this location for founding an abbey of the Order of Saint Benedict in the 8th century. This was to become an influential monastic community with large properties including Velbert, a settlement first mentioned in 875, located close to an old road connecting the rivers Wupper and Ruhr [Berger 1999, p. 282]. Other settlements in the study area that were founded before 1065 are Ratingen (mentioned in about 800 AD [Berger 1999, p. 233]), Gerresheim (a church dating back in the 9th century is very likely for this settlement [Wesoly 1994]), Hilden (developed from a single farmstead probably already in Merovingian times [Berger 1999, p. 145]), Homberg (9th century [Berger 1999, p. 150]), Himmelgeist (first mentioned in 904 AD [Dittmaier 1956, p. 152]), Hubbelrath (church in the 10th century [Dittmaier 1956, p. 226]), and Mettmann (near a Carolingian royal court [Berger 1999, p. 198]). Gruiten (first mentioned in about 1050 [Dittmaier 1956, p. 152]), and Wülfrath (first mentioned in the 11th century [Berger 1999, p. 300]) were probably also in existence in 1065. The settlement of Erkrath is most likely somewhat younger [Berger

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1999, p. 101]. Historians mention a close connection of Heiligenhaus with another old road known as Hilinciweg first mentioned in 875 [Dittmaier 1956, p. 91; Wesoly 1994]. A large proportion of the Heiligenhaus area belonged to the abbey Essen-Werden. The chapel erected in the 15th century was the nucleus for the settlement Heiligenhaus [Wesoly 1994]. Fig. 1 shows the churches in the study area that are listed in the Liber Valoris [Oediger 1967], a tax list of churches and monasteries set up in 1308. The settlements with churches depicted on the maps by Ploennies [1715] include the Liber Valoris churches, but also show some additions. The settlements on the map in Fig. 1 that have not been mentioned above are mostly not within the possible corridor of the *strata Coloniensis*. Some of these were also already established before 1065: the monastery of Kaiserswerth founded in 692 also held an influential position at that time [Dittmaier 1956, p. 139], Mintard (first mentioned in 874 [Dittmaier 1956, p. 139]), Sonnborn (first mentioned in 874 [Dittmaier 1956, p. 178]), Haan (first mentioned between 925 and 953 [Dittmaier 1956, p. 86]), Solingen (first mentioned in 965 [Dittmaier 1956, p. 200]), Wald (first mentioned in 1019 [Dittmaier 1956, p. 130]), Lintorf (first mentioned in 1050 [Dittmaier 1956, p. 22]), and Neviges (first mentioned in about 1050 [Dittmaier 1956, p. 154]).

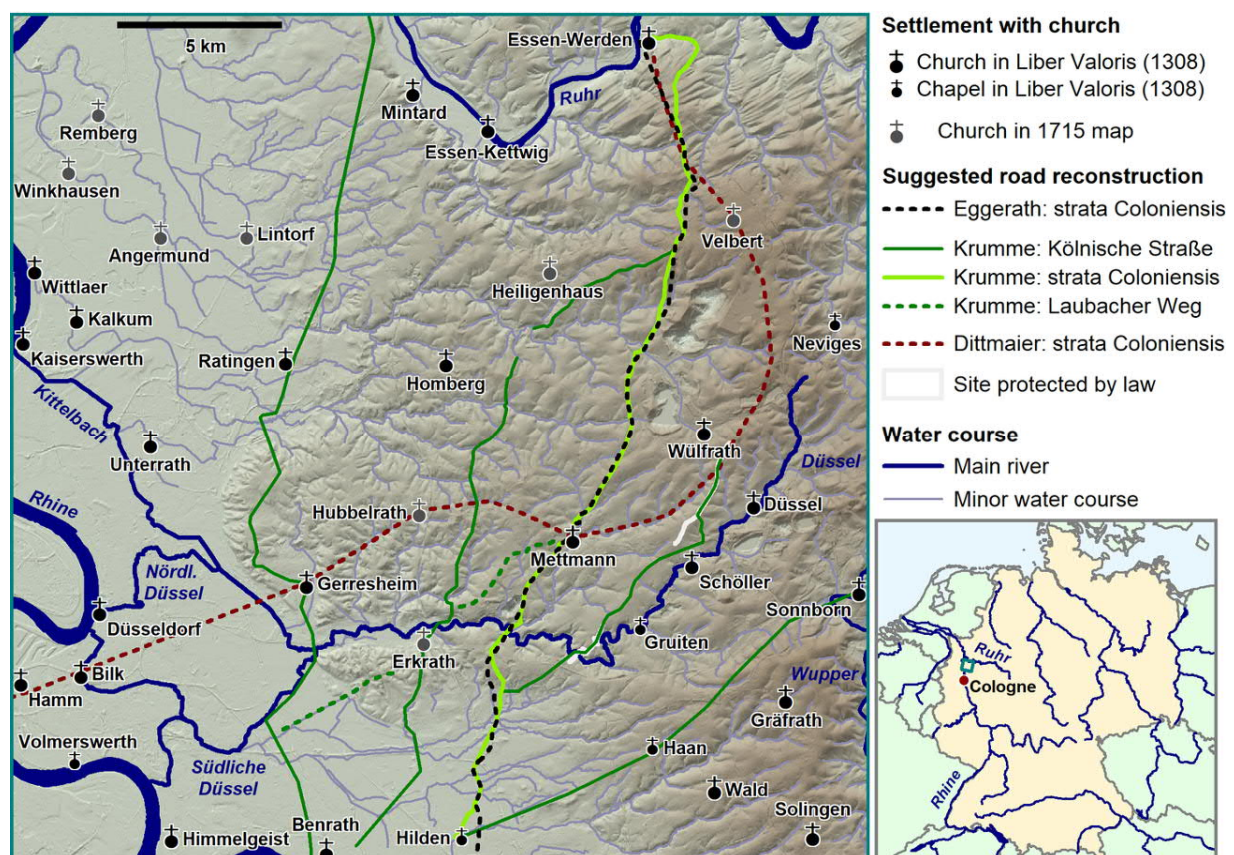


Fig. 1. The location of the study area in Germany (small map on the right). Large map: Several suggestions for the course of the *strata Coloniensis* and alternative old roads in the study area. Background: Modern elevation data, supplied by Geobasis NRW (© Irmela Herzog and Geobasis NRW)

After outlining the hypotheses concerning the course of the *strata Coloniensis*, the paper discusses several historical maps covering the study area or a part thereof, because most authors proposing courses of the *strata Coloniensis* rely on historical maps. This research greatly benefits from the fact that many historical maps are stored in open access web repositories. For instance, the earliest relevant map found dates back to 1598 but shows only a small part of the study area. Moreover, in North-Rhine Westphalia, the ordnance survey Geobasis NRW provides several web map services (WMS) that are useful for archaeological research: these include not only services based on historical maps created in the 19th century or later but also visualizations of Lidar data and orthophotos. The potential and limits of

the historical maps and the WMS layers will be investigated in view of the aim of identifying the course of the road from Essen-Werden to the Düssel that was in use in 1065 AD.

Often, archaeologists apply least-cost path calculations for reconstructing ancient routes [e.g. Herzog and Schröer 2019; Herzog 2013]. Most of these approaches use a cost model that includes a slope-dependent component. The study area is quite hilly south of Essen-Werden, but major modern modifications changed the relief since the Middle Ages (Fig. 1). These are clearly revealed in a DEM with a resolution of 25 m provided by Geobasis NRW. The relief changes include motorways (e.g. west of Neviges), and large areas of bulk material extraction, for instance west of Wülfrath. Another deep pit is visible close to the Düssel south of Mettmann. Close to this pit, the Neanderthal skeleton was found in 1856 in the course of limestone quarrying [Goebel 1984]. Starting in 1849, large-scale limestone quarries destroyed the scenic topography of the Düssel valley in this area with caves and steep slopes (known as Neandertal, i.e. the valley of Neander), that had previously attracted travelers from quite a distance [Ploennies 1715, p. 88; Goebel 1984]. Lime production by farmers is already mentioned in the description of the Ratingen area by Ploennies [1715, p. 94]. In the Solingen area, he records precursors of the metal working industry [Ploennies 1715, p. 88] and in the Schöller area, black marble was quarried [Ploennies 1715, p. 90]. In 1838, a railway connection between Düsseldorf and Erkrath was opened, which was extended towards Sonnborn in the years to follow [Goebel 1984]. Therefore the modern DEM is not an appropriate basis for reconstructing the medieval route from Essen-Werden to Cologne. Nevertheless, the final section of this paper will present an approach for estimating the effort of using an old road section by cost computations based on modern topographic data.

HYPOTHESES CONCERNING THE COURSE OF THE STRATA COLONIENSIS

Several alternative hypotheses concerning the course of the route have been published, they only agree on a fairly small section south of Essen-Werden (Fig. 1). Dittmaier [1956, pp. 219-220, 311] based his reconstruction of the road on old place names. In his view, the *strata Coloniensis* connected Werden to Velbert, proceeded south of Wülfrath, afterwards traversing Mettmann, Hubbelrath, and Gerresheim before reaching the River Rhine south of Düsseldorf. This hypothesis is supported by Gechter [2000]. As Dittmaier mentions only the main settlements along this route, this could only be mapped digitally with low precision. Digitizing the routes suggested by Krumme [1961] and Eggerath [1992/93] was easier and more precise because they mention modern road names and farmsteads on historical maps in their descriptions of the route. Krumme points out that several old routes were known as “road to Cologne” (in German: Kölnische Straße), which is the translation of *strata Coloniensis*. In his publication he lists five old roads to Cologne, and numbers them from west to east. In his view, number 3 is the most probable *strata Coloniensis*. According to Krumme, the Kölnische Straße 2 coincides with the Hilinciweg referred to above in connection with Heiligenhaus. This road was mentioned nearly 200 years earlier than the *strata Coloniensis*. Again two authors suggest different routes for the Hilinciweg, but it seems that all authors agree roughly on the section between Velbert and the point where the river Anger is traversed, i. e. the northern part of Kölnische Straße 2 depicted in Fig. 1 [Dittmaier 1956, pp. 91, 220, 311; Wesoly 1994]. Krumme’s research is based on 1:25,000 maps available in 1961, he tries to identify roads that proceed in roughly the same direction for a long distance. There is a gap in the Kölnische Straße 2 depicted in Fig. 1 because a limestone quarry interrupted the course on Krumme’s map. Another publication by Krumme [1964] describes the old road Laubacher Weg which connects Mettmann with Erkrath. This alternative route from Mettmann to the Düssel, combined with the northern part of Krumme’s *strata Coloniensis* is considered here as another possible course of the old route.

Krumme criticizes Dittmaier’s hypothesis regarding the *strata Coloniensis* due to its not very direct course and the location of the Düssel crossing point. In his view, the route suggested by Dittmaier consists of several old road sections belonging to different long-distance trade routes. Eggerath’s research is mainly based on old maps [Eggerath 1992/93] and her results coincide well with those of Krumme. The sites protected by law suggest another route, that is partly close to Krumme’s Kölnische Straße 4. One of these sites was published in the web information system on cultural heritage KuLaDig [LVR-Amt für Bodendenkmalpflege im Rheinland 2017]. The documents describing the sites mainly refer to maps created in the 19th century, whereas Eggerath’s argument relies on the maps by Ploennies [1715] and earlier maps covering a smaller area, supplemented by some historical data.

ROADS ON OLD MAPS

As mentioned above, the ordnance survey Geobasis NRW provides several WMS showing georeferenced historical maps. Moreover Open streetmap data was used for comparison. Fig. 2 illustrates that recent map data often does not

allow to identify single farmsteads mentioned in historical sources. When comparing the three WMS layers created based on 19th century maps, the accuracy is best with the most recent layer and decreases when going back in time. It seems that the earliest maps are not adequately georeferenced but a systematic shift in western direction was introduced. Gaps and areas not covered are an issue with the earliest map sheets. Moreover, in the earliest WMS layer, one map sheet in the northwest of the study area was replaced by a sheet created about 20 years later. Often, the place names are hardly readable from the two earlier WMS layers, the black and white WMS layer providing maps from the final decade of the 19th century show place names more clearly, but also substantial landscape change due to bulk material extraction and other human impact.

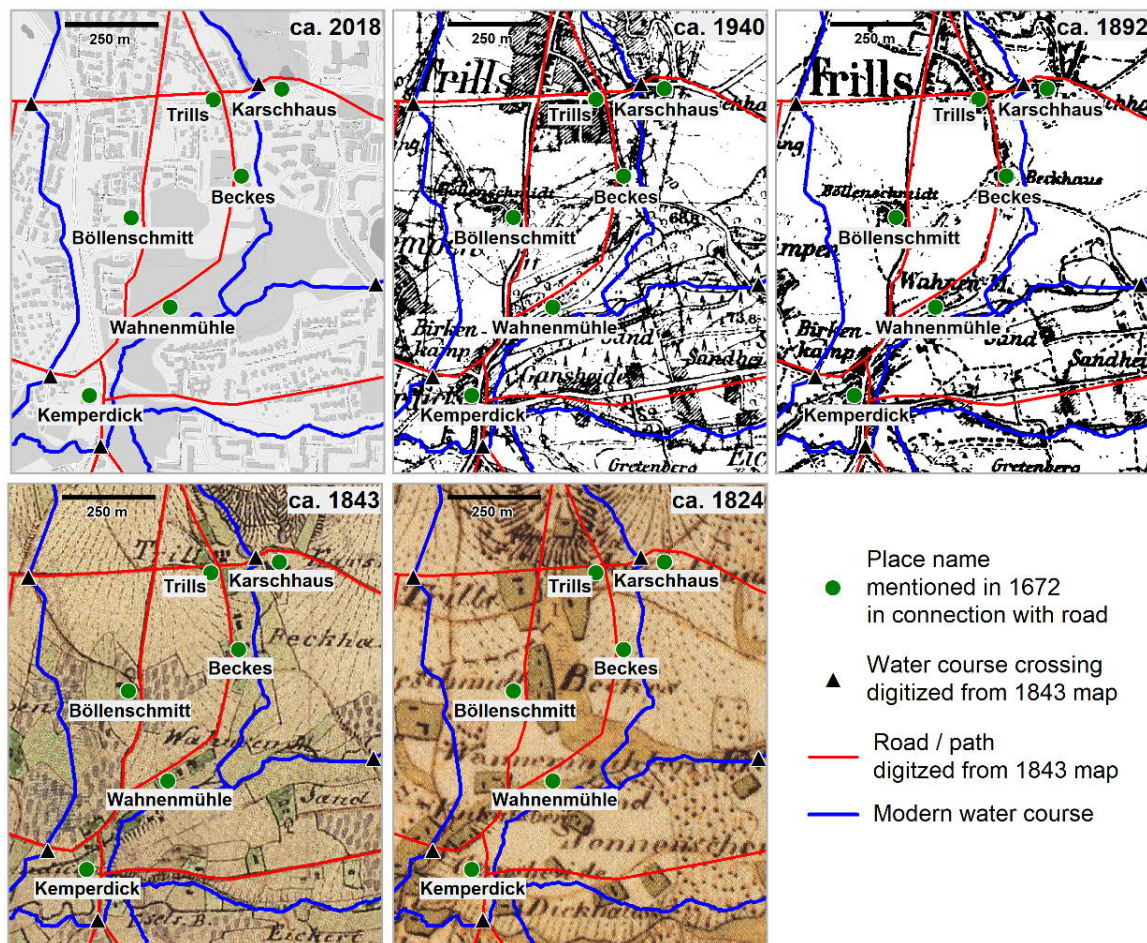


Fig. 2. Accuracy and other issues of WMS layers providing georeferenced historical maps. The place names mentioned by Eggerath [1992/93] were digitized from the 1892 map known as *Preußische Neuaufnahme*. WMS layers provided by Open streetmap and Geobasis NRW

The map set created by Erich Philipp Ploennies in the early 18th century [Ploennies 1715] covers a large part of the study area (Fig. 3). Very small settlements consisting of one farmstead only are depicted on these maps, but only the main roads are indicated so that many settlements appear disconnected. The distortion of this map set allows no straight-forward georeferencing, instead the roads were transferred approximately to modern maps taking all place names into account that could be found both in the 1715 maps and in later georeferenced WMS layers (see above). Typically, errors of 200 m or more cannot be avoided in this process. The results show that the courses of the *strata Coloniensis* suggested by Eggerath and Krumme agree well with a Ploennies road (Fig. 3 left). But also the sites protected by law are close to a Ploennies road. For the rest of this paper, the term site road is used for the Ploennies road connecting the protected sites. The course described by Dittmaier and Gechter is not quite as near to Ploennies roads as the routes suggested by the other authors. The older Hilinciweg is no longer depicted by Ploennies, this fact

illustrates issues with continuity. Moreover, the majority of the road sections of the Cologne routes proposed by Krumme and the Laubacher Weg are not shown on the Ploennies maps.

The von Müffling maps created in about 1824 show many roads and paths. Initially, the aim was to digitize only the main roads, but it soon became evident that deciding on the relevance of a brown line drawn on the map is quite difficult. The authors of the map sheets vary and so does the style. This is one of the reasons why the density of the yellow road network in Fig. 3 (right) varies. Moreover the impact of the two issues mentioned above are clearly visible, i.e. the replaced map sheet and the systematic error. Nearly all sections of the suggested old roads coincide with a road or path depicted on a von Müffling map.

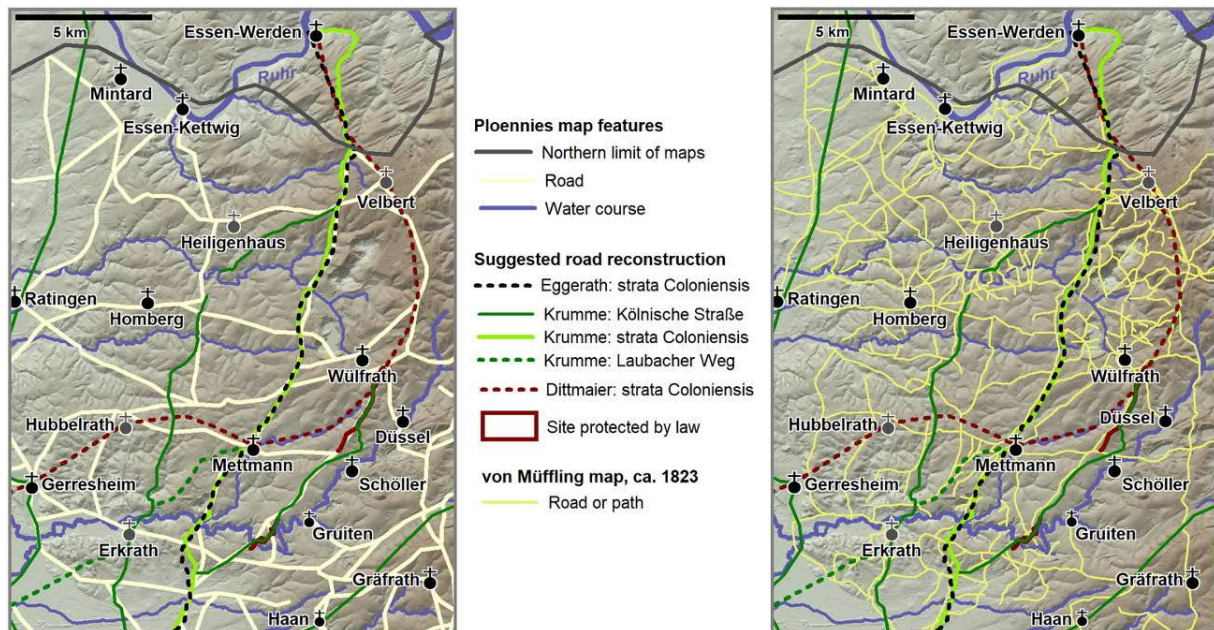


Fig. 3. Comparison of the suggested old roads with (a) Ploennies roads (left) and (b) roads or paths digitized from the WMS layer showing the earliest georeferenced maps (ca. 1824) in the study area (right). DEM data provided by Geobasis NRW

So neither the Ploennies map set nor the von Müffling maps provide a decision on the correct course of the *strata Coloniensis*. Therefore a search for earlier historical maps covering the study area and depicting roads was started. The earliest map meeting these requirements that came to our knowledge was created by Johann Michael Gigas (approximately 1582-1637?) in 1620 (Fig. 4). However, this map does not show any roads starting at Essen-Werden. Moreover, some errors are evident: Homberg is depicted west of the road connecting Essen-Kettwig with Ratingen, though this town is located east of Ratingen (cf. Fig. 1). Gruiten is shown south of the Düssel River, but in fact is located north of this water course.

The image data base of Amsterdam University presents a relevant map published in an atlas attributed to Henricus Hondius (1597–1651), which dates between 1636 and ca. 1680 [Hondius 1636]. This map is probably based on earlier maps by Gerardus Mercator, because Jodocus Hondius, father of Henricus, bought Mercator's plates after the death of the famous German cartographer [Garfield 2014, p. 150]. A slightly modified copy of this map is available in an online repository of the Bern and Basel Universities [Valck and Schenk ca. 1670/1690]. According to the metadata for this map, Gerard Valck (1651–1726) and Pieter Schenk (1660–1711) are the authors/contributors.

This map shows a road connecting Werden with Hilden via Mettmann. So this map seems to support the hypothesis of Eggerath and Krumme. However, even on the historical map this road is not as direct as the other roads depicted. There is a detour near the town of Haan which is even more striking when drawing the road on a modern map background taking the locations of places into account that could be identified both on the historical and a more recent map (Fig. 5). 70 corresponding place names were found, allowing to assess the map distortion.



Fig. 4. Section of a map by Gigas [1620] showing the study area and some roads

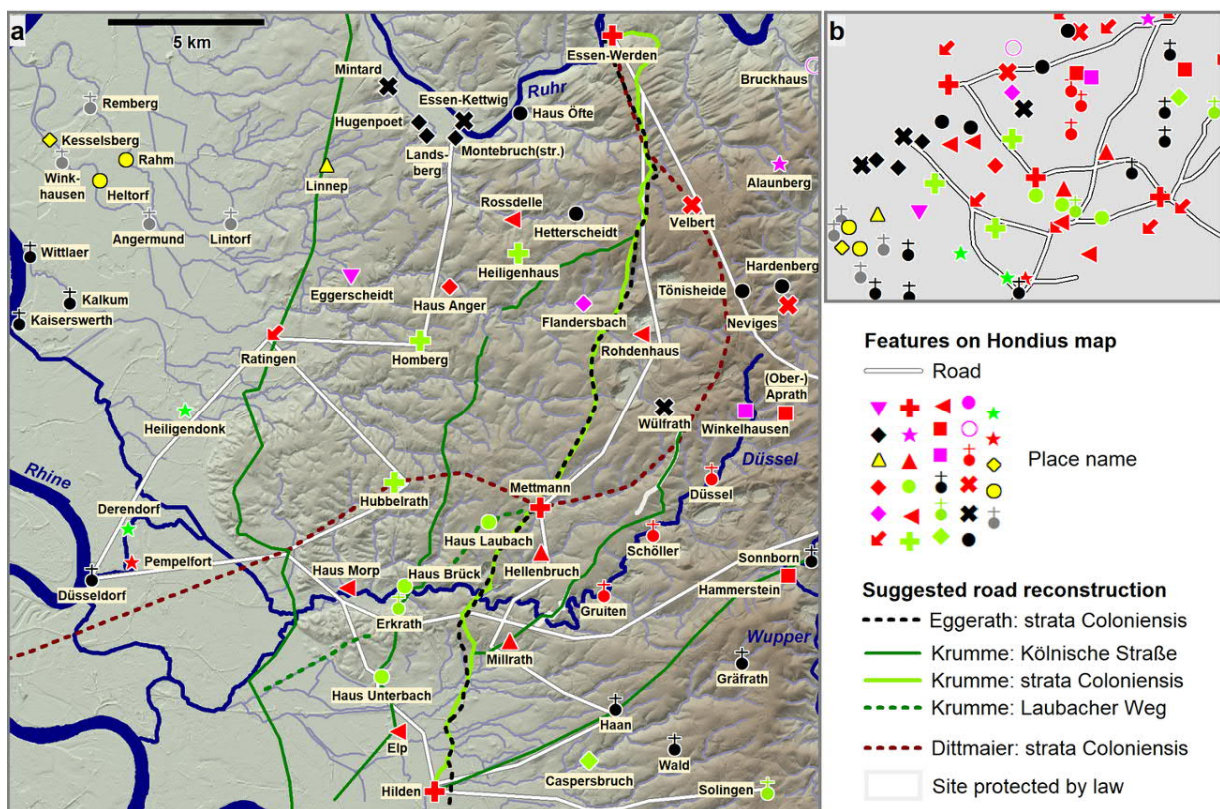


Fig. 5. Result of identifying places on the Hondius map and a more recent georeferenced map. On this basis, the roads shown on the Hondius map (b) were digitized on a modern map background (a). Comparison of the symbol pattern on the Hondius map and the modern map shows distortions and gross errors

The Hondius map shows roughly the same road between Essen-Kettwig and Ratingen as Gigas, the error concerning the location of Homberg is also visible in the Hondius map. So these more general early maps are not reliable. Therefore more detailed early maps covering a small part of the study area were considered with a focus on maps showing Düssel crossings. About 3 km west of Erkrath, the Düssel is split in several water courses; this probably has not changed since 1065, although some modifications of the rivers and creeks can be seen when comparing modern and historical maps. A plausible assumption is that the *strata Coloniensis* crossed the River Düssel before the split point because only the river name is mentioned in the document without any additional specifications. Between the split point and Gruiten more than twenty bridges or fords could be digitized from the 1843 maps (Fig. 6).

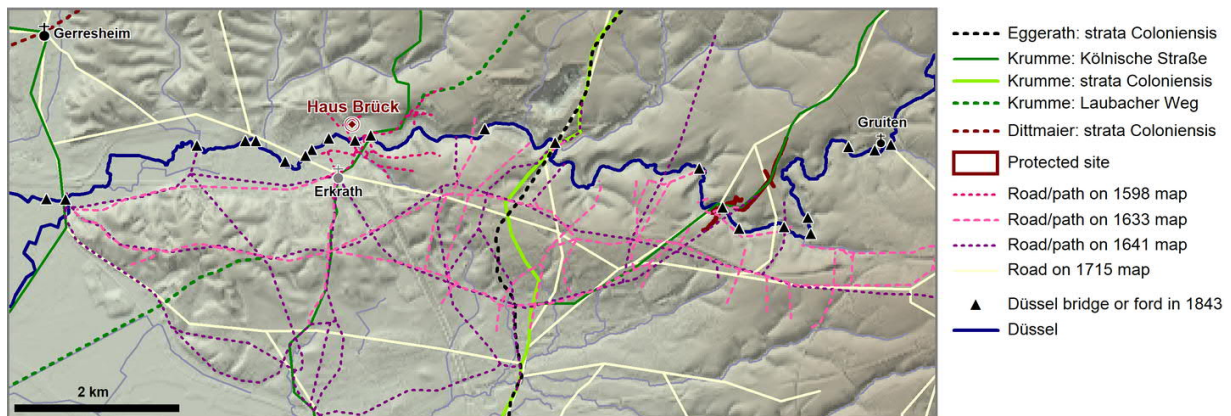


Fig. 6. Düssel crossings depicted on historical maps and suggested by authors discussing old roads to Cologne. DEM data provided by Geobasis NRW

The earliest map showing a Düssel crossing found shows the property of Haus Brück north of Erkrath [Mercator 1598]. This map was created in the course of legal proceedings. According to Osmann [2016], the fortified house Haus Brück is closely related to a stone bridge and was first mentioned in 1258. An earlier date for the first mention is given by Dittmaier [1956, p. 90], i.e. 1148. Berger [1999, p. 73] mentions that German place names ending with *brück* usually indicate locations where water courses could be traversed with the help of a bridge and that these places are often found close to old trade routes. However, the bridge depicted on the Mercator map leading to Haus Brück seems to be of local importance only. The roads and paths on this map were transferred to a modern map background as described above (Fig. 6). The Laubacher Weg and the Kölnische Straße 2 use a bridge near Haus Brück, and the 1598 map shows paths running in the direction of the Laubacher Weg. A small bridge east of Haus Brück might belong to this long distance route, but most path sections roughly coinciding with the Laubacher Weg appear like minor local paths on the old map.

Another old map recently found in a federal archive covers the relevant part of the Düssel River [Landesarchiv NRW Abteilung Rheinland 1633]. The map was created in 1633 in the course of legal proceedings concerning hunting rights. In view of this purpose, geographic features important for delimiting the hunting territory are shown, whereas other features are missing or drawn sketchily. For instance, east of the town Gruiten, the River Kleine Düssel (small Düssel) joins the Düssel River, but only a very small part of the Kleine Düssel is depicted on the map. Moreover, no bridge close to Haus Brück is mapped. On the map, a bridge crossing both the Mettmanner Bach and the Düssel River close to the point where these two streams join appears disconnected from the road network. This bridge is near the Düssel traversing location of the *strata Coloniensis* routes suggested by Krumme and Eggerath. Another Düssel bridge depicted is within or very close to one of the protected site areas. But the road traversing this bridge does not proceed in southern direction but seems only of local importance. The only road traversing the Düssel with a continuation in southern direction on the map is shown west of the steep cliffs of the Neandertal. After about 700 m, this road joins another road proceeding in southwestern and later in western direction. No section of these roads coincides with roads shown on Ploennies maps. In general, the agreement between the Ploennies map roads and those depicted on the 1633 map is fairly low (Fig. 6). Additional Düssel bridges depicted on the 1633 map can be found (i) near Winkelsmühle only about 250 m west of the protected site area, (ii) near Bracken, about 800 m east of the protected site area, and (iii) close to Eigen, about 400 m north of Winkelsmühle.

Another local map showing Düssel crossings originated from 1641, a copy drawn in 1811 was scanned and the roads shown transferred to a modern map background [Kaehsman 1641]. The map depicts three paths that traverse the River Düssel: one of the Düssel crossing locations agrees quite well with a protected site, another one is located close to the place where the *strata Coloniensis* routes suggested by Krumme and Eggerath traverse the Düssel. But south of this crossing location the distance between the roads transferred from the 1641 map and the course suggested by Krumme and Eggerath exceeds 500 m. It is unlikely that this large difference was caused by an error in the transferring process. The roads running in west-east direction on the 1633 and the 1641/1811 map coincide quite well. But the differences with respect to the Düssel River crossing locations are substantial. This might be due to updates introduced by the person copying the 1641 map in 1811.

Nearly all roads and paths depicted on the 1598, 1633 and 1641 maps are also visible on the map created in about 1843, suggesting that a large majority of paths and roads established in the past remained in use, though the importance of some of them decreased. But the Ploennies roads do not agree as well with the roads and paths on the earlier maps as expected. Therefore it is very difficult to assess the continuity of the routes used in medieval times.

ARCHAEOLOGICAL EVIDENCE

Most of the old road sections protected by law are in use today. An exception is the area depicted in Fig. 7. The Geobasis WMS combining orthophotos taken in the time interval between 1988 and 1994 shows crop marks indicating the course of the road that is depicted on historical maps created in the 19th century. In 2006, an excavation consisting of four trial trenches with a length of up to 54 m recorded remains of a sunken road (Fig. 7). Only modern artifacts were recorded during this excavation, the trial trenches did not provide any evidence for the *strata Coloniensis*.

This example illustrates the fact that dating of the routes detected in aerial images often is an issue. Moreover, there are some minor differences between the two 19th century maps, which may be attributed to small changes of the route layout or to inaccuracies of the older map. The way the road is drawn on both maps suggests that this part was a sunken road at that time, maybe the course of a deeply incised sunken road bordered by fields cannot be changed easily? The number of presumed sunken road depictions on the 19th century maps is quite large. However, most of these features are no longer visible in modern Lidar data due to industrial development and new settlement areas. In the study region, even the Lidar visualizations of areas used by agriculture often show the impact of past human activities. If sunken roads can be detected at all in modern Lidar data, these are mostly still in use and their slopes are often maintained so that they appear more regular than in their initial state.

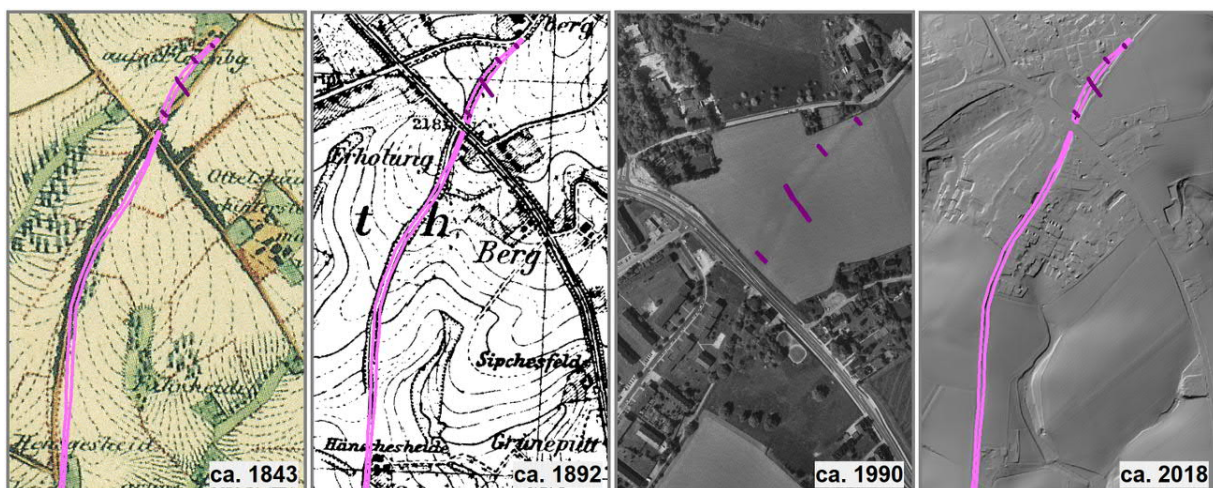


Fig. 7. Location of part of the protected site and some trial trenches carried out in 2006. The length of the longest trench is 54 m. WMS layers provided by Geobasis NRW.

The trial trenches covering a section of the Hilinciweg did not produce any finds, only a ditch was documented that could be related to an old road. The sites and monuments data base of the Rhineland Commission for Archaeological Monuments and Sites in Bonn records many other archaeological investigations in the study area close to the courses of the roads considered. Most of these resulted in early prehistoric finds (highlight: Neanderthal skeleton) or documented remains of early industrial activities. Some report forms of archaeological investigations mention medieval structures or finds in the vicinity of the road courses discussed in this paper, but only the general term Middle Ages is used. So the archaeological evidence does not clearly support any of the hypotheses concerning the course of the *strata Coloniensis*.

COMPARISON OF THE DIFFERENT ROUTE SUGGESTIONS

The suggested routes agree approximately for the first part until a location about 1.5 km northwest of Velbert is reached. Only the part immediately after leaving Essen-Werden differs somewhat: the map created in 1843 shows a detour avoiding the steep slopes south of the settlement. But the townscape drawn in 1572 shows sunken roads coming down the hills [Nicke 2001, pp. 186-187]. Moreover, a map of the Werden area created in the first half of the 17th century shows a direct road towards the south [Wesoly 1994, Plate 4]. Therefore the more direct route seems more plausible.

The comparison of the different route suggestions presented in the next paragraphs focuses on the section between the point about 1.5 km northwest of Velbert mentioned above and the Düssel crossing. The comparison includes five routes: (1) the route suggested by Eggerath, (2) the route suggested by Eggerath from Essen-Werden to Mettmann, afterwards using the Laubacher Weg until Haus Brück, (3) the site road, (4) Kölnische Straße 2 as described by Krumme, and (5) the route suggested by Dittmaier and supported by Gechter.

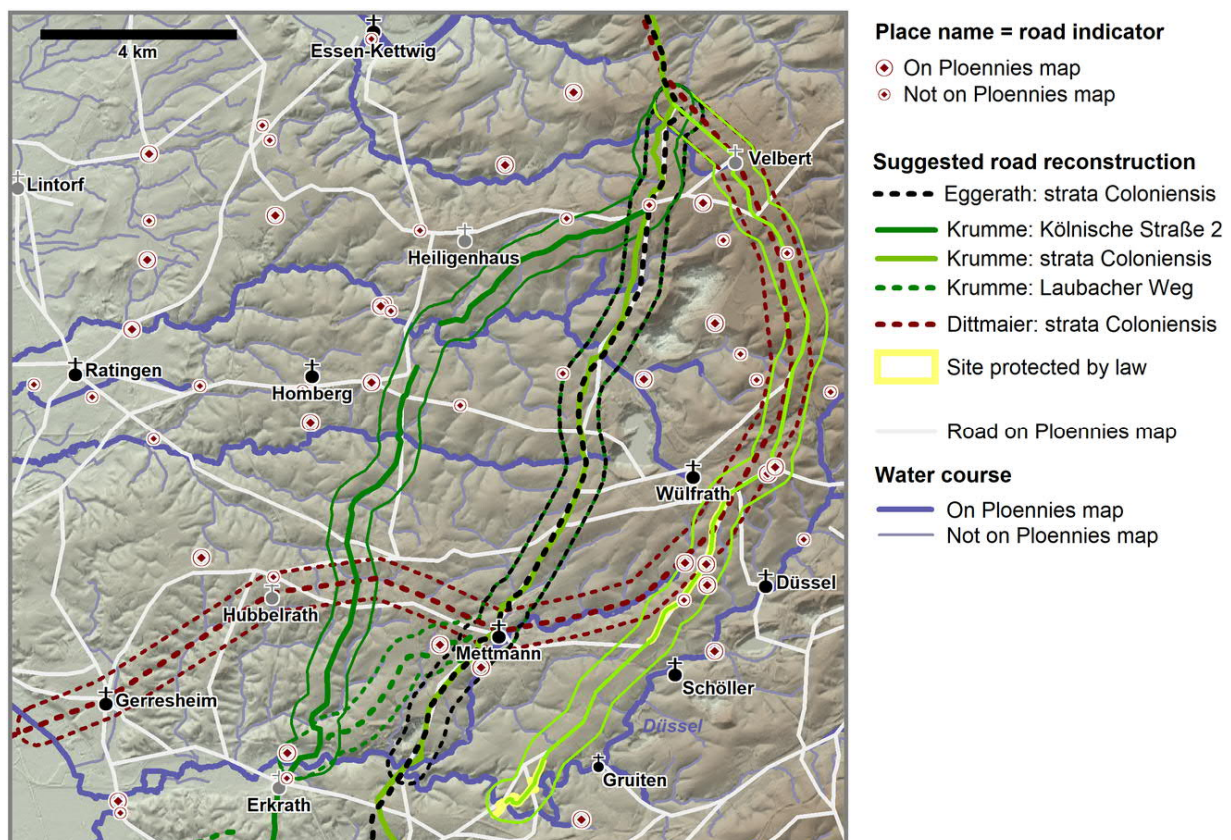


Fig. 8. Map showing 400 m buffers for the sections of the suggested road reconstructions to be compared and place names indicating roads found on historical maps

The first criterion used for comparison is the number of place names indicating the presence of a road in the vicinity of a suggested route. The location of 85 place names referring to bridges (such as Haus Brück mentioned above), fords, roads, and check points at boundaries were digitized from the WMS layers providing georeferenced historical maps (Fig. 8). Out of these place names, 40 were already recorded on the Ploennies maps, and these are considered more significant than the rest. For each of the five routes to be compared a 400 m buffer was constructed and the number of road indicating place names counted. The largest number of such road indicators was found for the site road (Tab. 1).

Additional criteria are derived from the research aiming to reconstruct old roads by least-cost path calculations in the hilly region south of the study area. It was found that both crossing of water courses and slope have an impact on route selection [Herzog 2013]. The old routes were created by a tradeoff between (1) length of the path, (2) number and difficulty of traversing water courses, and (3) avoiding steep slopes. The *strata Coloniensis* course suggested by Eggerath seems to be the shortest option of the routes considered, not only for the section to the Düssel crossing, but also when taking the straight-line distance from the Düssel crossing to the cathedral in Cologne (i.e. the final destination of the road) into account (Tab. 1). Another criterion for the road layout is the number of water courses traversed. The water courses depicted on the maps by Ploennies are considered more relevant than the rest, so these are counted separately. The lowest number of water course crossings was found for the site road (Tab. 1).

The total elevation difference indicates the presence of relevant gradients. Due to the human impact on the landscape mentioned in the Introduction, reliable calculations of the total elevation difference of the hypothetical old routes should not be based on modern digital elevation data. The first topographic map set covering the study area with contour lines was created towards the end of the 19th century (Fig. 2 – ca. 1892). But the relief at that time already differed significantly from the medieval relief. Therefore the time-consuming task of digitizing the contour lines from the late 19th century maps seemed not worth-while. Besides, tests in areas with only minor changes in the topography showed that these contour lines are of limited accuracy [Lechterbeck 2008].

Table 1. Comparison of the different route suggestions

| Feature | Eggerath | Eggerath + Laubacher Weg | Site road | Köln. Str. 2 | Dittmaier |
|--|------------------|-----------------------------|------------------|------------------|------------------|
| Number of 1715 road indicators within 400 m band | 1 | 2 | 5 | 1 | 3 |
| Total number of road indicators within 400 m band | 2 | 3 | 6 | 2 | 5 |
| Length → length of 1936-45 route | 15.7 → 15.9 km | 17.5 → 17.8 km | 18.0 → 18.3 km | 18.0 → 18.2 km | 25.5 → 27.0 km |
| Straight-line distance from Düssel crossing to the Cologne cathedral | 31.7 km | 31.8 km | 31.0 km | 31.8 km | 33.3 km |
| Number of Ploennies water course crossings | 3 | 3 | 0 | 3 | 0 |
| Total number of water course crossings | 5 | 6 | 0 | 7 | 6 |
| Total elevation difference | 715 m | 764 m | 554 m | 926 m | 1037 m |
| Tobler's time estimations [Tobler 1993] for walking in both directions | 197 min; 205 min | 219 min; 228 min | 222 min; 229 min | 230 min; 240 min | 336 min; 345 min |
| Düssel crossing efficiency of modern road/path | 0.75 | 0.86 | 0.57 | 0.86 | |
| Median road slope of Düssel crossing | 6.5 % | 3.1 % | 8.9 % | 3.1 % | |
| Median DEM slope of Düssel crossing | 28.2 % | 4.4 % | 20.0 % | 4.4 % | |

The approach for calculating the elevation difference should take into account that the precision of the digitized routes is fairly low for some route sections as mentioned above. Therefore, for each of the route candidates considered, a nearby route using the closest road or path shown on the map set created in the years 1936 to 1945 (scale 1:25,000) was digitized, thus ensuring that steep natural or man-made steep slopes such as gravel pits close to the past road are avoided. In general, the 1936 to 1945 route is longer than the approximate route, both lengths are

given in Tab. 1, separated by an arrow. For each 1936 to 1945 route, the total elevation difference is calculated on the basis of the modern digital elevation model (DEM) with a resolution of 25 m. The lowest total elevation difference resulted for the site road (Tab. 1).

The distribution of slopes derived from the 1936 to 1945 route elevations are illustrated in the left part of Fig. 10. The boxplots show that the slopes of the site road are significantly lower than those of the other route alternatives. The gradients of the Dittmaier road are in general lower than those of the Eggerath route options, and the slopes of the Kölnische Straße 2 mostly exceed those of the other routes considered.

Estimating the time required for travelling a road based on a slope-dependent function combines the two criteria “length of the road” and “avoiding steep slopes”. For the two directions of each 1936 to 1945 road the well-known Tobler hiking function [Tobler 1993] was applied in order to calculate the time needed in minutes. The Tobler function was chosen because it was successfully applied in several least-cost studies and does not have some of the disadvantages of other functions used for estimating walking time. This function models a fast walker, with a speed of 6 km/h when descending a gradient of 5 %. Walking velocity depends not only on slope, but also on the age, health, and load of the walker, gender, vegetation, weather conditions, size of the group and some other factors. The time estimations given by the Tobler hiking function can be regarded as the lower limit. The route suggested by Eggerath results in the lowest travelling time estimations (Tab. 1). Deviating from the Eggerath route by walking the Laubacher Weg to Haus Brück takes 10 % longer according to the Tobler estimations. The time penalties for taking the site road is only slightly higher and the trade-off with the number of water course crossings might have led to a decision in favor of this route. The route suggested by Dittmaier is much more time-consuming than the other alternatives; therefore this course of the *strata Coloniensis* is highly unlikely.

However, it is not known if the decision for a route was based on walking time or if other means of transportation were more important for route selection. Unfortunately, functions estimating travelling time depending on slope for carts or wagons, pack animals or for riding on horseback are not readily available. But it is well-known that the critical slope for humans is higher than that for wheeled vehicles: whereas well-trained walkers ascend gradients of up to 45 % directly, most vehicle roads avoid slopes beyond 12 or 15 %, hairpin turns are often found when steep slopes are to be negotiated by such roads. If transport by humans prevailed initially and wheeled transport became more important later on, the steeper routes may have been replaced by longer, but less cumbersome roads. Therefore the site road might be later than the other routes.

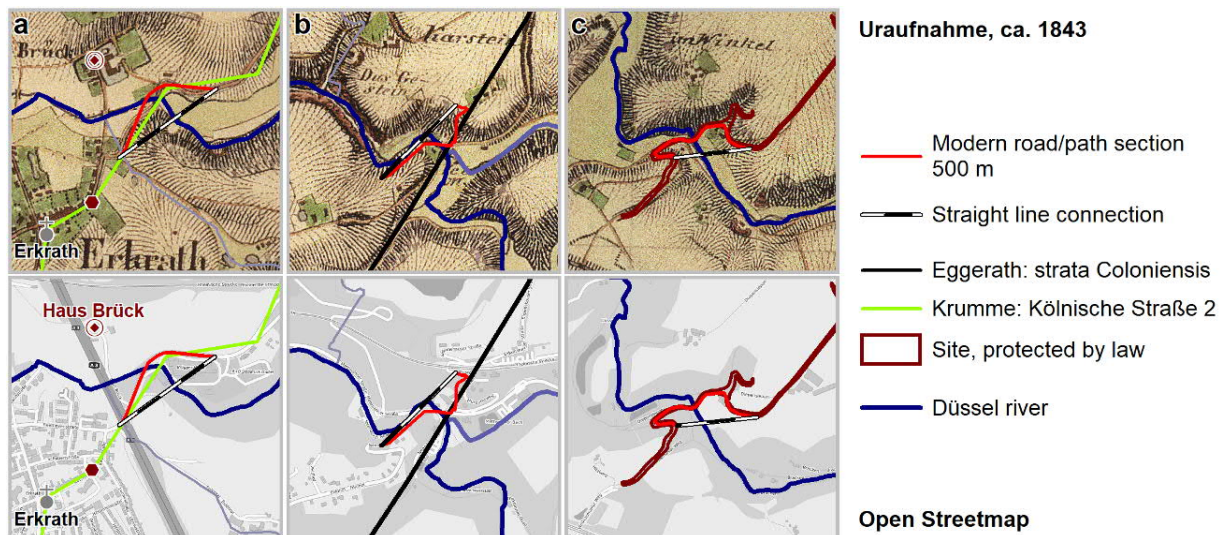


Fig. 9. Düssel traversing locations: a) Haus Brück, b) Neandertal, c) protected site

The difficulties of crossing the Düssel might have been decisive for selecting the route. Therefore the Düssel traversing locations close to Haus Brück (Kölnische Straße 2, Laubacher Weg), Neandertal (Eggerath and Krumme) and the site road are analyzed in more detail; the Düssel crossing of the Dittmaier course was not considered because its location is unclear and this route seems quite unlikely when considering the criteria presented above.

In the final three rows of Tab. 1, three key figures are presented that assess the difficulties of the Düssel crossings. Due to lack of reliable historical data, these figures are based on a modern DEM with a cell size of 25 m and modern roads, therefore underestimating the obstacles of traversing the Neandertal. For each Düssel crossing location, the modern road or path traversing the river was digitized for about 500 m, with the Düssel separating the road section in two parts of approximately equal length (Fig. 9). The efficiency is calculated by dividing the length of the straight line connection between the two end points of this road section by the road section length. The optimal efficiency is 1, i.e. no detour was necessary to traverse the river. The efficiency of the Düssel crossing close to Haus Brück is best (Tab. 1).

For each 500 m road section, the median slope was computed (Tab. 1). The boxplots with label “Road slope” in Fig. 10 illustrate the distribution of these slopes. The road slope close to Haus Brück is considerably lower than that of the other crossing locations considered. The slope of a road on a contour line is 0, but to the left and right of the contour line steep slopes may be found. This slope is derived from the DEM by GIS software and is in general steeper than the road slope.

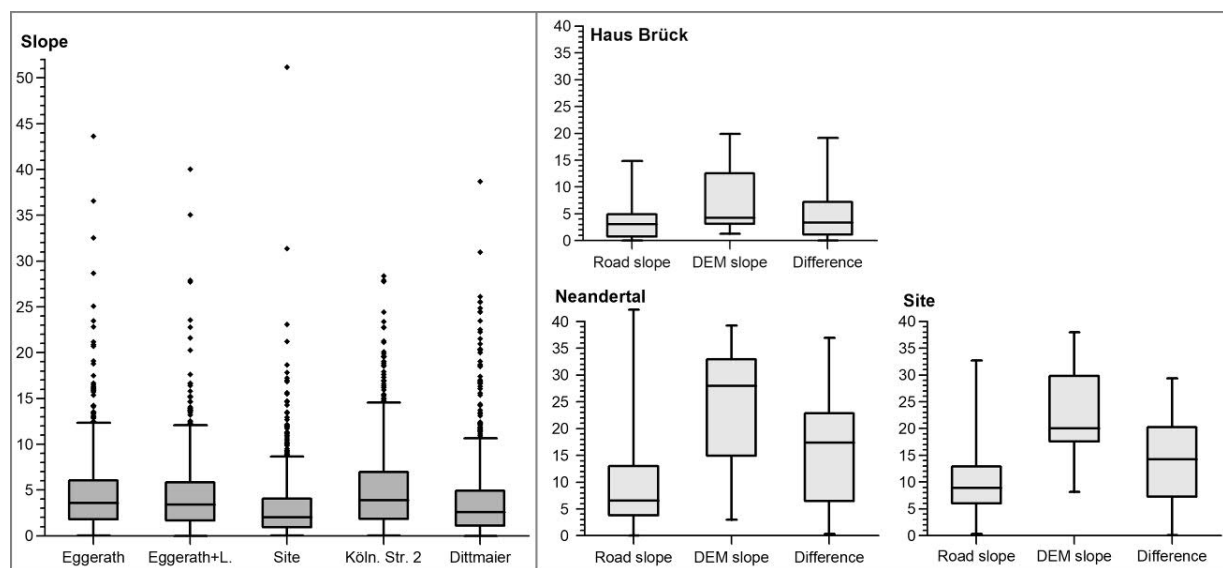


Fig. 10. Left: boxplots illustrating the distribution of slopes for the five alternative routes considered. Right: boxplots showing the slope distributions at the Düssel traversing locations

The median DEM slope of the Neandertal and the protected site Düssel crossings is a lot higher than that of Haus Brück (Tab. 1), this difference is also clearly visible in the corresponding boxplots (with label “DEM slope” in Fig. 10). The effort of road construction is considerable if the difference between road slope and DEM slope is high. For this reason, the difference between the two slope values was calculated as well (Fig. 10). The outcome of the computations outlined above clearly shows that the Düssel crossing near Haus Brück is easiest.

CONCLUSIONS

Although a lot of data was compiled and analyzed with the aim of deciding on the course of the route between Essen-Werden and the Düssel mentioned in a historical document in 1065, no final decision could be reached. Some archaeological evidence of old roads can be found close to every suggested course of the *strata Coloniensis*, but conclusive finds dating these road remains are still to be detected.

The WMS layers combining georeferenced sheets of 19th century maps show a large number of roads and paths that fit quite well to all hypotheses published concerning the course to the *strata Coloniensis*. The earliest more general maps that cover the study area and show some main roads were created more than 500 years after the road was first mentioned. Hardly anything is known about the continuity of medieval roads, so the main routes depicted on these maps may be later, and the initial routes still in use at that time, but of minor importance. Besides, the location of

several places is misrepresented on these maps, therefore transferring the roads to a modern map does not provide reliable results. The Ploennies maps [1715] cover nearly the complete study area, record every farmstead and do not show any gross errors. It was possible to transfer the main roads depicted on these maps to a modern map background. The course of the *strata Coloniensis* suggested by Eggerath and Krumme, but also the course implied by several protected sites coincide quite well with Ploennies roads. But the Hilinciweg first mentioned in 875 is not shown on a Ploennies map, though all authors discussing this old route agree upon the fact that this old road is still visible on 19th century maps. It seems plausible that this route was used all the time, but was less important in 1715 than in 875. Consequently, the *strata Coloniensis* might not coincide with one of the Ploennies roads. Early local maps showing also minor roads are probably more relevant than more general maps depicting only the most important roads of that time. The roads and paths of three such maps covering part of the study area surrounding the Düssel River were transferred to a modern map background. Some of the Ploennies roads running through these map areas are not depicted on the older maps. This underlines that continuity of roads is not to be taken self-evident for the study area considered.

Three places for crossing the Düssel are analyzed in the final section of this paper. The analysis reveals that the slopes near Haus Brück are lowest, for the two alternative Düssel traversing locations, steep slopes may present a significant obstacle. But the elevation differences to be negotiated on the way from Essen-Werden to the Düssel crossing is lowest for the route implied by the protected sites. Depending on the criterion considered, either the course suggested by Eggerath and Krumme or the site road performs best (Tab. 1). Therefore it is quite likely that one of these two courses coincides with the *strata Coloniensis*, and both courses are depicted on the Ploennies map, so they were created at least 300 years ago.

The additional Düssel crossings documented on the map created in 1633 suggest some future research: in the area of Eigen sunken roads are visible in the Lidar data supplied by Geobasis NRW. These roads are running in the direction of the river Düssel north and south of the river. So this Düssel crossing location might also have been in use for quite some time. West of the Neandertal, the steep slopes north of the Düssel show some traces of sunken roads in the Lidar visualizations as well, further traces can be detected south of this potential crossing location. For a final assessment of the exact location, the chronological time frame, and the importance of the Düssel crossings discussed in this paper, additional historical documents or archaeological investigations are required.

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