Journal of Maps

ISSN: (Print) 1744-5647 (Online) Journal homepage: https://www.tandfonline.com/loi/tjom20

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To cite this article: Guido S. Mariani, Filippo Brandolini, Manuela Pelfini & Andrea Zerboni (2019) Matilda's castles, northern Apennines: geological and geomorphological constrains, Journal of Maps, 15:2, 521-529, DOI: 10.1080/17445647.2019.1625823

To link to this article: https://doi.org/10.1080/17445647.2019.1625823

Published online: 17 Jun 2019.

JOURNAL OF MAPS
2019, VOL. 15, NO. 2, 521–529
https://doi.org/10.1080/17445647.2019.1625823

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Matilda's castles, northern Apennines: geological and geomorphological constrains

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ABSTRACT
The positioning and construction of castles in ancient times responded not only to strategic opportunity, but also to the issue of geomorphological risk. We investigated castles and strongholds built in the era of the *Great Countess* Matilda of Canossa in part of the northern Apennines (Italy), in order to study the relationship between their positioning and the distribution of geomorphological and geological hazards. We observe how the location of castles follows clear patterns of avoidance of potential hazards: castles are kept far from the main fault systems and stream networks, and are mainly at a safe distance from landslide- and badlands-susceptible terrains. The knowledge of Medieval communities on landscape hazards was sufficiently advanced to minimise risks, while maintaining the strategic value of fortifications.

ARTICLE HISTORY
Received 8 March 2019
Revised 15 May 2019
Accepted 28 May 2019

KEYWORDS
Geomorphological risk; landslides; castles; Middle Ages; Apennines; Matilda of Canossa

1. Introduction

Castles and strongholds represent a relevant component of both the cultural and geological heritage of a territory. Fortifications, frequently positioned on natural buttresses, enhance the value of geosites (*sensu* Reynard, 2004) in terms of geohistorical importance (Bollati, Zucali, & Pelfini, 2014; Booth & Brayson, 2011). Their location and distribution mainly respond to logistic and strategic needs related to their cultural function. Nevertheless, castle – as well as settlement – positioning in past times had to deal also with georisks (Roberts, Nadim, & Kalsnes, 2009). Today, modern urban planning and construction techniques take full account of the geological and geomorphological characteristics of building areas (McCall, 1992). To this end, our current advanced knowledge of underground and surface geological processes allows accurate predictions of terrain fragility and its possible impact on the vulnerability of structures and infrastructures. The development of geology as a science is quite recent, dating to the beginning of the 19th cent. CE. However, very precise assessments of landscape stability and geological hazards are also often present in the archaeological and historical past. The establishment and development of settlements reflects the balance between strategic opportunity and geomorphological stability, especially for large structures. A careful evaluation of risks and benefits is testified by those same structures, which have fulfilled their function during their time and in many cases still survive to this day. Many areas of Europe saw during the Middle Ages the development of castle and fortification systems, which had to interact with different geomorphological hazards (Knight & Harrison, 2013). Among other areas, the Alps and Apennines are particularly characterised by a marked geomorphological instability, mainly triggered by seismic and hydrogeological processes.

Studies focusing on risk management and mitigation in ancient times are scanty. In this paper, we investigate an area of the northern Apennines (Italy) in which a gradual expansion of fortifications following the spread upward of human settlements in Medieval times. Our main aim is to verify how the location of these structures aligns to the modern knowledge of geomorphological risk. and how these constrains impact on the necessity to establish a capillary control of the territory (Figure 1). In particular, we consider the system of castles and strongholds built in the era of Matilda of Canossa and compare their distribution with the geological and geomorphological context of northern Apennines in order to investigate the perceived knowledge of geomorphological hazards in that time.

2. Area of study

The mapped area (Figure 1) lies in Northern Italy, inside the Emilia-Romagna region, and corresponds to a slice of the Apennine chain from the main watershed to the terraces at its foot (Reggio Emilia province). The area is bordered to the East and West respectively by the Secchia and Enza rivers, to the South by the Apennine main watershed, and to the

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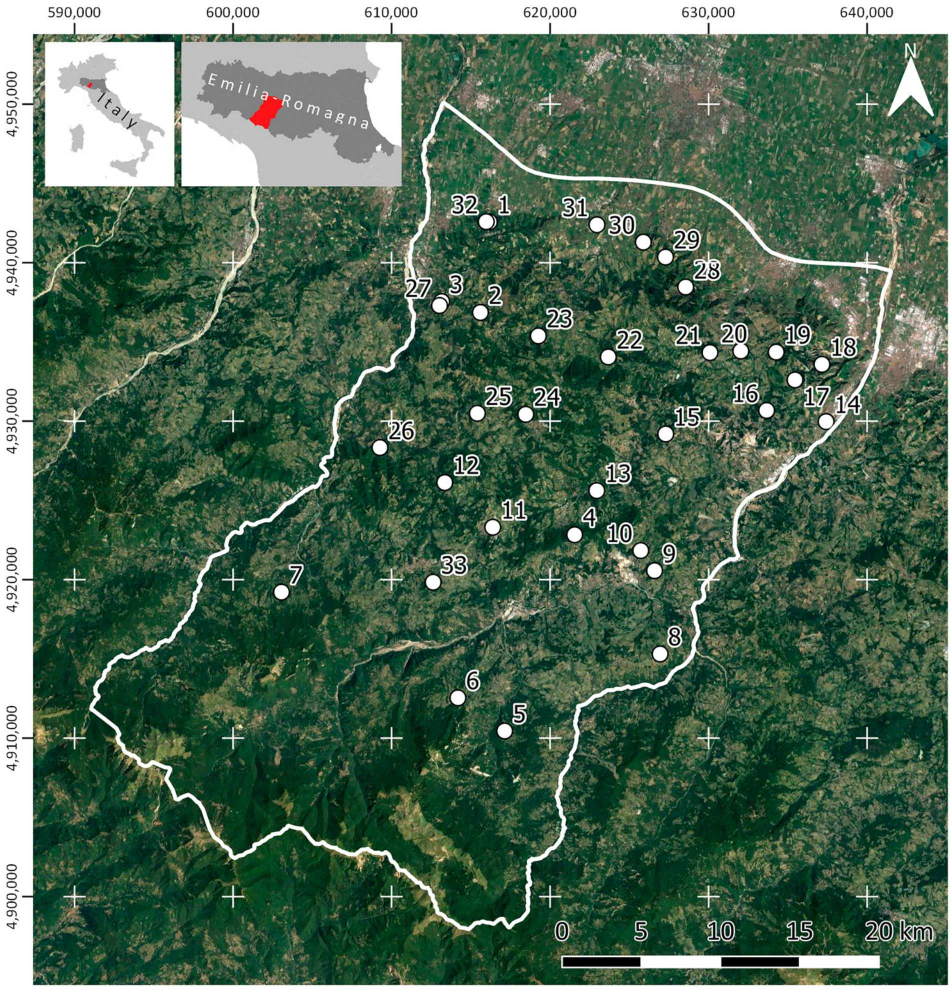

Figure 1. GoogleEarth™ satellite imagery illustrating the study area and indicating the distribution of the Matilda's castles; the insets show the position of the region in northern Italy. Coordinate system: UTM 32N, grid units in metres. Key: (1) Monte Zagno; (2) Canossa; (3) Rossena; (4) Carpineti; (5) Cà Vecchia; (6) Minozzo; (7) Teggie; (8) Massa; (9) Bebbio; (10) Casteldaldo; (11) Torre Felina; (12) Montecastagneto; (13) Mandra; (14) Castellarano; (15) Baiso; (16) Gavardo; (17) San Valentino; (18) La Rocca; (19) Montebabbio; (20) Rondinara; (21) Viano; (22) Montalto; (23) Paullo; (24) Sarzano; (25) Leguigno; (26) Crovara; (27) Guardiola; (28) Borzano; (29) Montericco; (30) Albinea; (31) Mucciatella; (32) Monte Lucio; (33) Pietra di Bismantova.

North by the connection of the Apennine range to the southern margin of the Po Plain. Altitudes range from 58 m a.s.l. at the foot of the piedmont to the 2121 m a.s.l. of Mt. Cusna, the highest peak of the area (Mariani, Cremaschi, Zerboni, Zuccoli, & Trombino, 2018). From a geological standpoint, the northern portion of the Italian Apennines is an orogenic arc verging NNE composed by heavily deformed sedimentary units. Rock formations both precede and concur with the formation of the chain mainly during the Secondary and Tertiary Eras (Bosellini, 2005; Vai & Martini, 2001). Foreland deposits as well as elements of oceanic crust dislocated by compressive uplift compose the local bedrock. The inner arc of the chain, beyond the watershed, is structurally complex and characterised by extensional tectonics and consequent rifting and uplift (Vai & Martini, 2001). The outer arc is composed by a regular sequence of outward migrating deformational belts characterised by widespread folds and thrusts following the direction of the deformation (Gelati, 2013). Consequently, the stratigraphy of the northern Apennines follows a classic series of silicoclastic turbidite foredeep wedges (Pini, 1999; Vai & Castellarin, 1993) arcing from the inside to the outside of the chain and variously folded and bent. From a lithological point of view, turbiditic claystones and sandstones dominate the outcropping lithologies, interspersed with calcareous formations mainly composed of limestones and marls. Ophiolitic domes, as well as isolated metamorphic outcrops appear sparsely in the studied area.

Extensive fault systems produced by the complex compressive and extensive tectonics characterise this part of the arc. The shallow location of the main faults combined with the active uplift of the external rim of the outer chain enhances greatly the surface effects of seismic events. Strong earthquakes appear both in historical records (Boschi et al., 2000; Guidoboni & Comastri, 2005), and in recent catastrophic events in the northern (2012 Emilia seismic sequence: Tertulliani et al., 2012) and the central Apennines – see for instance the 2016–2017 Central Italy seismic sequence (Chiaraluce et al., 2017).

The main geomorphological features of the region are typical of strongly deformed mountain environments. Folds and thrusts produced during the uplift of the chain remain in the landscape as elevated reliefs, forming monoclinal ridges and occasionally tabular structures eroded and partially dismantled by surface processes (Main Map). Among these, slope processes are particularly widespread: the northern Apennines are characterised by very active slope dynamics due to their distinctively soft lithologies combined to the high frequency of seismic events. A variety of gravity- and water-controlled slope landforms dot the landscape, ranging from gently rolling hills and badlands (in Italian *calanchi* or *biancane*) on clay materials to jagged cliffs modelled in more resistant sandstone or limestone formations. Landslides of different nature and extension deeply affected the territory in the past, often in response to climate variations (Bertolini, 2007). Slope instability and landslide reactivation phases are also recorded for the present time (Bertolini & Pellegrini, 2001). When coupled with the action of running water, intense slope incisions produce steep erosional cliffs and gorges, or solifluction lobes and mass-wasting deposits. Apennine badlands take different aspects and classifications (Bollati, Reynard, Lupia Palmieri, & Pelfini, 2016). Many of these erosive phenomena are presently active and often enhanced by human impact. The highest part of the chain was noticeably modelled by glaciers until the Last Glacial Maximum (Losacco, 1949, 1982).

3. Historical and archaeological context

The establishment of strongholds along the Tuscan-Emilian Apennines belongs to a general fortification process that interested many European regions starting from the 10th cent. CE. In Italy, the encastellation process (in Italian *incastellamento*) aimed to contrast the threat of Saracens, Magyars, and Norseman invasions through the construction of fortified castles (Settia, 1984). Originally, the regent of the Italic Kingdom was the only one in charge of granting to the local lords the right to build strongholds, but after the disruption of royal authority in Italy (mid-10th cent. CE) many powerful noble families started to construct their own castles (Augenti, 2000; Augenti, Cirelli, Fiorini, & Ravaioli, 2010; Borrelli et al., 2014; Settia, 1984). By the 11th cent. CE, the north Italian political power was scattered in several local authorities with deep social and cultural consequences. In the Emilia-Romagna and Tuscany regions, the Canossa rulers led the reorganisation of the landscape with the construction of both defensive and ecclesiastic buildings. The political power of the Canossa family started with Adalberto Atto of Canossa (977–984 CE) and reached its apogee under the reign of his great-granddaughter Matilda of Tuscany (1052–1115 CE) – aka *the Great Countess*, one of the most influential personalities of her time.

In the study area, Matilda enhanced the Canossa fortification system with the renovation of castles, and likely built new ones. The exact establishment of Canossa castles is not certain: dating is limited at *ante quem* (i.e. *before*) or *post quem* (i.e. *after*) data derived from medieval chronicles as well as cadastre (Table 1). In fact, historical documents report that 90 out of 186 castles in the province of Reggio Emilia were founded between the 10th and 11th cent. CE (Galetti, Fiorini, Morini, & Zoni, 2014; Settia, 1984), but the archaeological records rarely confirm this periodisation. Canossa castles, indeed, were restored during the Italian *Comuni* (i.e. city-states) period (Manenti Valli, 1987; Saggioro et al., 2018), and the most ancient phases documented are dated between the 12th and 13th cent. CE (Brogiolo & Cagnana, 2012). The Canossa fortified system guaranteed protection over the main ways that connected the Po Valley with Central Italy through the Apennines (Zoni, Mancassola, & Cantatore, 2018). The historical and political influence of the Canossa dynasty during the 10th and 11th cent. CE led to create a sort of mythic aura around one of the most prominent medieval noble families in Europe.

Recently, several investigations were carried out to study the Canossa defensive system. In particular, archaeological excavations included the castles of: Canossa (Manenti Valli, 2001; Saggioro et al., 2018); Carpineti (Lenzini, 2015) (Figure 2); Pizigolo (Toano) (Mancassola, Cantatore, & Zoni, 2018); Sarzano (Baricchi, Podini, & Serri, 2015); Pietra di Bismantova (Mancassola et al., 2014); Monte Lucio (Quattro Castella) (Augenti, Fiorini, Galetti, Mancassola, & Musina, 2011); Rossanella (Manenti Valli, 2009; Zoni, 2015).

4. Materials and methods

Historical and archaeological data on castles come from recent archaeological studies (Augenti et al., 2011; Baricchi et al., 2015; Lenzini, 2015; Mancassola et al., 2014; Mancassola et al., 2018; Manenti Valli, 2001; Manenti Valli, 2009; Saggioro et al., 2018; Zoni, 2015), as well as from an online local database (Provincia di Reggio Emilia, 2019). These sources allowed to select the most suitable sites for the purpose of this study. As stated above, the chronology for the establishment of the chosen castles is indicative and known only in general terms.

The cartographic effort on the study area took place mainly through remote sensing, with the acquisition and processing of topographical, geological and risk-related data, compared with the historical-archaeological data. To draw the Main Map, we acquired data both from the field and from digital archives. Reference topography derives from contour lines (5 m) retrieved from the Geological Survey of Emilia-Romagna

Table 1. List of Canossa's dynasty castles in the study area.

Castle	Year of foundation	Canossa ruler	Period
Canossa*	940 (*post quem*)	Adalbert Atto of Canossa	977–984 CE
San Valentino	1010 (*ante quem*)	Tedald of Canossa	984–1007 CE
Rondinara	1010 (*ante quem*)		
Massa	1035 (*post quem*)	Boniface III, Margrave of Tuscany	1007–1052 CE
Mucciatella	1037 (*ante quem*)		
Castellarano	1039 (*ante quem*)		
Montalto	1052 (*ante quem*)		
Albinea	1057 (*ante quem*)		
Rossena*	1070 (*post quem*)	Matilda, the *Great Countess* of Tuscany	1052–1115 CE
Minozzo	1070 (*ante quem*)		
Sarzano*	1070 (*ante quem*)		
Carpineti*	1077 (*ante quem*)		
Montebabbio	1092 (*ante quem*)		
Baiso	1100 (*post quem*)		
Monte Lucio*	1100 (*post quem*)		
Pietra Di Bismantova*	1100 (*post quem*)		
Pizigolo*	1100 (*post quem*)		
La Rocca	1107 (*ante quem*)		
Montecastagneto	1111 (*ante quem*)		
Bebbio	1115 (*ante quem*)		
Mandra	1115 (*ante quem*)		
Torre Felina	1116 (*ante quem*)		
Monte Zagno	1147 (*ante quem*)	–	–
Casteldaldo	1184 (*ante quem*)		
Paullo	1197 (*ante quem*)		
Leguigno	1197 (*ante quem*)		
Guardiola/Rossena*	1200 (*post quem*)		

Note: All dating derives from medieval historical documents, which give only a ante quem or post quem foundation year. The majority of Canossa castles is likely to have been established or enhanced during the reign of the Great Countess Matilda. The star indicates castles still standing or recently interested by archaeological studies. Information about each site is available online (Provincia di Reggio Emilia, 2019).

Figure 2. An example of a castle from the study region: (a) view of the monoclinal relief hosting the Carpineti castle (indicated by the arrow); (b) detail of the monoclinal-type relief illustrating the escarpment and the outcrop of sandstone strata; (c) a detail of the Carpineti castle.

(Regione Emilia-Romagna, 2017). The construction of a Digital Terrain Model (DTM) through GIS software (QGIS version 3.4) provided the basis for terrain analysis, as well as slope and hillshade layers produced from this model. Geological cartography and related names and acronyms were retrieved from the 1:10000 scale geological map constructed by the Geological Survey of Emilia-Romagna (SGSS, 2019). Naming conventions for the geological formations conform to the Geological Map of Italy at 1:50000 scale (CARG Project: ISPRA, 2019). Geomorphological risk-related data for the territory (hydrographic network, landslides, badlands, fault systems) were provided at 1:10000 scale by the Geological Survey of Emilia-Romagna (SGSS, 2019). In our work, we chose to focus on structural features and slope processes: other than producing the most widespread landforms in the landscape, these represent the most important factors influencing terrain stability of the region and therefore infrastructure stability. To compare the potential impact of geomorphological features on castle locations landslides and faults on the map were transformed into point layers (100 m equal interval points for fault lines, centroids for landslide polygons, area-weighted random points for badlands polygons) and visualised as influence areas through analyses of density based on kernel method (di Lernia et al., 2013; Silvermann, 1986), with a radius of 500 m. This method allows to produce heatmaps representing the main hotspots for the considered features, in order to identify high-risk areas (Bonnier, Finné, & Weiberg, 2019; Danese, Lazzari, & Murgante, 2008).

5. Results

5.1. Distribution of castles and strongholds strategy

The distribution of castles inside the landscape seems to follow some common principles. Most of the castles are located in the North, in the lower portion of the outer Apennines: this area is also the more exposed to potential threats from the well-populated Po Plain. Their distribution then thins out towards the higher (southern), less populated part of the chain. Most of the buildings lie on slopes, over peaks, ridges or escarpment rims, and generally on high ground (Figure 3). Mid-slope positions appear with less frequently; only one castle among those investigated (Rondinara) is built directly on a valley floor. Slope steepness can vary, reaching extreme cases: some castles, in fact, occupy the rim of low and high scarps (such as Torre Felina, Guardiola, and Pietra di Bismantova). All castles are clearly far from waterways: only one (Rondinara) is found directly at the passage of a watercourse. In all other cases, proximity to a stream is frequent, but always from an elevated position (for example, Castellarano lies on a hill directly above the river), or at considerable distances. Moreover, when comparing dates of foundation retrieved from literature (Table 1), the distribution of castles in the region appears to follow a chronological trend. While such records are not completely accurate, it is still visible a colonisation expansion in time towards the inner Apennines, coupled with a progressive increase in the number of strongholds in the areas already settled.

5.2. Geological and geomorphological features

From the geological layers of the Main Map appears a series of evident folds and thrusts, oriented NE to SW

Figure 3. Examples of geological and geomorphological settings of selected castles (satellite imageries from GoogleEarth™): (a) the Pietra di Bismantova castle on top of a mesa-type relief; (b) the Carpineti castle on the rim of a monocline structure; (c) the Canossa Castle on a residual hill of sandstone surrounded by badlands developed on marls and clays; (d) the Guardiola (bottom) and Rossena (top) castles built on top of ophiolite domes.

perpendicular to the direction of the main orogenetic deformation, which represent the main structural motif of the Apennine chain (Abbate, Bortolotti, Passerini, & Sagri, 1970). Although spread throughout the area, these are more linear and better visible to the North, in the outer portion of the chain, where these structures are more recent and have undergone only minor disruptions. The main faults similarly lie in a NE to SW direction; lesser faults are instead mainly perpendicular to the previous ones. Most of the faulting concentrates in two separate areas. A major portion of faults and seismogenic structures rests on an elongated belt located in the outer portion of the arc only a few kilometres from the plains. The upper half of the chain to the South hosts the main part of the remaining lineaments, including the majority of the thrust faults.

The geomorphological evolution of this sector of the Apennines strongly relies on the presence of compressional structures. Folds and thrusts divide the landscape in a series of variously set monoclinal structures, mostly parallel to the chain and in correspondence to the outcrop of anticlines and overthrusts. A few isolated mesas can also be found: some of them have become iconic elements of the local landscape. For instance, the Pietra di Bismantova geosite (Borgatti & Tosatti, 2010) that is an elevated sloping limestone tabular mesa surrounded by vertical cliffs (Mancassola et al., 2014). Monoclinal structures are common and variously related to the channel network. Streams and rivers mostly flow around these structures, but sometimes cut them: in many instances these large structures are broken by the passage of a stream. This often happens near fractures and fault systems, which produce structural weaknesses that water can exploit as a breach. The expansion of watersheds and the action of other surface processes work to hide the presence of large monoclinal structures, especially in the upper part of the chain, where they are often found as broken isolated elements not immediately traceable to longer escarpment alignments.

The other major constraint to castle distribution is the high occurrence of landslides. These are uniformly distributed over the territory in response to a substantial similarity of its lithological features and decrease in frequency only in the lowest and highest portions of the chain. A vague clustering in strips parallel to the main lineament of the chain does appear, especially in the North. The map takes into consideration both active and inactive landslides. We argue though that many of the latter are dormant, and subject to potential reactivation, in accordance with the dynamic setting of the Apennines (Dramis & Bisci, 1998; Piacentini, Ercolessi, Pizziolo, & Troiani, 2015). It is therefore plausible to assume that most of these landforms could have already been active 1000 years ago, with only a fraction of them being completely posterior.

6. Discussion: military strategy vs. geomorphological risk

The primary function of a fortification is to provide defence and control over a territory (Creighton, 2002, 2012): its position in the landscape must therefore facilitate this purpose. Oftentimes, remote elevated positions and vantage points represent ideal locations, since a larger visual on the territory allows efficient control and the possibility for easy communication with a community scattered on the territory. The reduced accessibility and relative isolation in the landscape provided by elevation also enhance their defensibility. On the other hand, locations close to main roads and passages (for example Rondinara and Carpineti) allow a strict control of traffics and a closer relationship with the settlements themselves, with the added value of physical protection. However, such ideal conditions need to come with terms with the constraints found in the landscape (Creighton, 2002).

Considering the geomorphological setting of the area, there is a visible correspondence with the construction of castles and the main monoclinal structures. Several ridge locations are in fact directly associated with the top of larger structural forms (for example Viano, Baiso, Sarzano and, much more spectacularly, Carpineti; Figures 2 and 3b); in other cases, although not on the main ridge, castles are still located in their vicinity. Isolated reliefs are another chosen location: in fact, several castles are located both on mesas or on isolated mounds formed by selective erosion of sedimentary successions (Torre Felina and Pietra di Bismantova; Figure 3a), and on isolated domes of resistant ophiolitic materials (Guardiola, Rossena, and Minozzo; Figure 3d).

Of the various elements of risk, hydrology is perhaps the most evident and the simplest to mitigate. Outside clear strategic necessities, as in the case of Rondinara, all the castles are in fact at enough distance from riverbeds and the surrounding floodplains to easily avoid the effects of floods. In general, while proximity to the main water network is usually very important for settlements, apparently castles can be more independent from this resource.

The relationship between castles and fault systems, highlighted by kernel density (Figure 4a), seems to follow a rather common pattern of avoidance. In the area of the piedmont, the first line of castles looking over the Po Plain is mainly isolated and far from faults or overthrust systems. In the inner portions of the chain, fortifications tend to be either outside or at the perimeter of high concentrations of fractures. Alternatively, there are examples of castles located near fault systems of small dimensions (Massa) or very close to single isolated faults (Carpineti). This strategy seems to achieve a dual purpose. Such distribution leads to low seismic risk for constructions, which in a high-hazard area

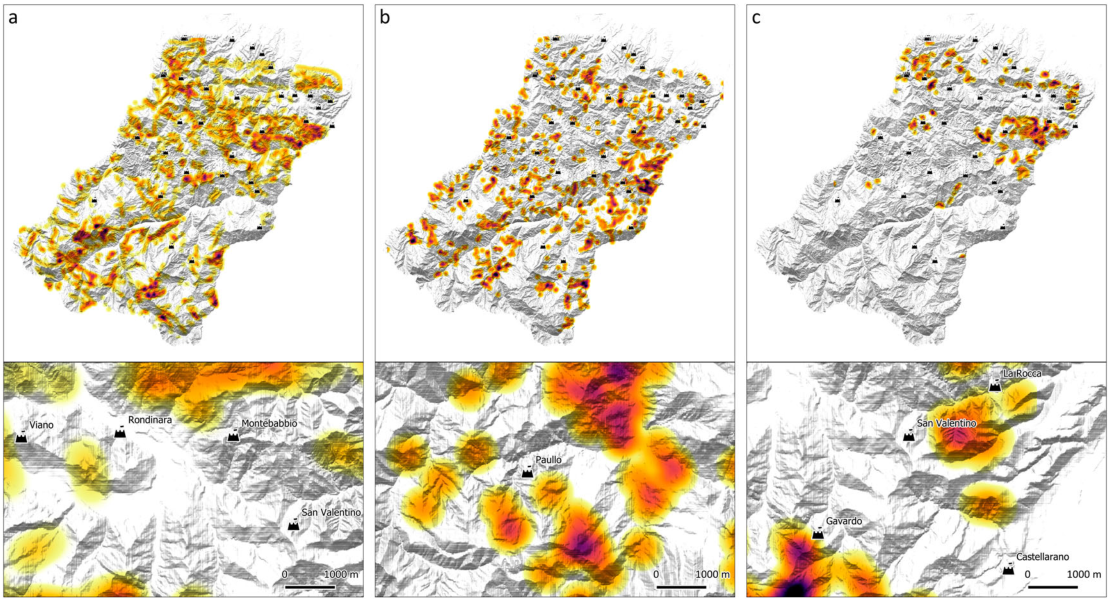

Figure 4. Analyses of density of the investigated geological and geomorphological parameters locations based on kernel density. Elaborations represent the whole region (see Figure 1 for scale) and details for each: (a) analysis of density of faults vs. castles location; (b) analysis of density of landslides vs. castles location: (c) analysis of density of badlands vs. castles location.

such as the Apennines is a considerable advantage. Furthermore, it also allows to rely on stronger slope stability, lowering the likeliness of hazardous slope phenomena triggered by fracture-enhanced substrate degradation.

Conversely, the relationship with landslide events, which are more uniformly spread over the territory, is less straightforward (Figure 4b). Kernel density shows how in many cases castles seem to be located close (within a few hundred metres) to single landslides or inside areas containing evident slope hazards. These are often connected to the presence of steep slopes and scarps (Pietra di Bismantova, Carpineti) or to widespread badlands formation (Monte Zagno, Canossa) (Figure 4c). Nevertheless, oftentimes a short linear distance does not imply influence, as many castles occupy positions unrelated to these landforms, sometimes as different slopes or different lithologies (Figure 3c). A large majority of the castles is anyway quite far from unstable areas, especially on the piedmont, where the occurrence of landslides is rare. At a first glance, the occurrence of fortifications in the proximity of these landforms would indicate a lower attention or ability to recognise this type of geomorphological hazard. Nevertheless, this interests only a fraction of cases. Many factors need to be considered: of all processes, landslides are very complex events, which can be triggered and enhanced by multiple factors such as structural instabilities, lithology, hydrology, seismicity and climate, especially in the northern Apennines (Bertolini & Pellegrini, 2001). To assess with accuracy the areas at higher risk, and even more to effectively mitigate such risk, is still today a considerable task (Lee & Jones, 2004; McCall, 1992).

7. Conclusions

The positioning and construction of castles during Matilda's Age was the result of both military strategy and geomorphological safety. A careful balance between these two aspects was fundamental in the choice of the most suitable locations for important and expensive enterprises, as testified by the various examples found in the territory. We can therefore assume that in this period of the Middle Ages advanced knowledge on rock engineering and behaviour was already available. Even without the modern understanding of geology, the grasp of medieval populations on the variety and occurrence of landscape hazards was sufficiently advanced to allow an efficient assessment of the terrain, and especially of slope stability. This knowledge also extended to the main surface processes and the fundamentals of geomorphological and hydrogeological risk mitigation (floods, landslides, probably avalanches).

In conclusion, the mapping of Matilda's castles and the analysis of their distribution referred to geodiversity and geomorphological features and changes (Pelfini & Bollati, 2014; Reynard & Giusti, 2018) suggest a multi-layered planning in the identification of locations for each stronghold. We suggest that even in past times military strategy and territorial control were only two of the factors followed in planning infrastructures, and the awareness of the many possible environmental risks of a region was higher than we would expect.

Software

QGIS 3.4 was used for all cartographic design, including geodatabase production, digitisation, satellite photo visualisation. DTM analysis was performed with the help of tools from SAGA GIS 2.3.2 and GRASS GIS 7.4.2.

Acknowledgments

We kindly acknowledge A. Perego for fruitful suggestions on GIS analyses. We are grateful to the staff of the Hotel Matilde (Carpineti, RE) for their hospitality. We also thank the reviewers and the associate editor for their useful suggestions.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Geological and geomorphological mapping was performed in the framework of the SUCCESSO-TERRA Project financed by the Italian Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR), grant PRIN20158KBLNB (P.I. M. Cremaschi). The elaboration of GIS data was supported by the Italian Ministry of Education, University and Research (MIUR) through the project Dipartimenti di Eccellenza 2018–2022 (WP4 – Risorse del Patrimonio Culturale) awarded to the Dipartimento di Scienze della Terra 'A. Desio' of the University of Milano. Further financial support from Università degli Studi di Milano, Progetto Linea 2 (2017) entrusted to AZ.

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