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ORIGINAL ARTICLE

Geoheritage Assessment and Potential Geotouristic Enhancement in Mountain Environments: a Test-Site in the Northern Apennines (Italy)

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Abstract
This work proposes an integrated methodology to inventory and quantitatively assess the geosites located in a mountain context of northern Apennines. The geological and geomorphological heritage and the historical, cultural, and religious heritage produce a complex cultural landscape. Such a context is expressed sometimes through monumental examples and other times through hidden or invisible points of interest. In particular, the test area is located between the Emilia-Romagna and Toscana regions (high valley of Tiber, Senatello and Marecchia rivers), including part of three protected areas. The choice of these test sites has been addressed also considering that meaningful historical sites and cultural testimonies are widely present, in addition to the geological and geomorphological features. Amongst these sites, we have considered the Mt. Faggiola Castle ruins, where Dante was possibly hosted when exiled from Florence, the St. Francesco route from Rimini to La Verna, the Historical Park of the Gothic Line of Badia Tedalda and the background of one of the most iconic Leonardo da Vinci's portraits, la Gioconda.

Keywords Geosite · Geodiversity · Geomorphology · Geoheritage assessment · Georoutes · Geotourism

Introduction

Starting from the establishment of the first European geoparks in 2000, the geological culture has been gradually spreading throughout the world, proposing a model of sustainable development that integrates geological knowledge with local culture. In fact, one of the main goals of UNESCO Global Geoparks is to provide integrated sustainable development for the direct benefit of its local population. Promotion and transmission of traditional knowledge, valorisation of local products, development of respectful outdoor activities through Geotourism and empowering local people and ethnic groups are keys to what must be sustainable development in geological protected areas (Bouzekraoui et al. 2018; Brandolini et al. 2007, 2011; Comănescu et al. 2017; Lazzari 2013).

The co-existing of geologically interesting and impressive landscapes, together with historical and cultural values, can surely improve the experience of tourists, thus increasing the geotouristic potential of sites and their effectiveness in engaging the public (Brandolini et al. 2011; Guerra and Lazzari 2021).

Based on these premises, we have developed the present work, where we present the inventory and quantitative assessment of seven geosites located in the higher sectors of the Senatello, Tiber and Marecchia river valleys, the last also known as *Valmarecchia*, between Emilia-Romagna and Toscana regions (Fig. 1), aimed to enhance the geotouristic potential of this sector of northern Apennines and propose a different reading and interpretation of the territorial values, to increase the local tourist attraction by enhancing the geotourism proposal.

In this area, geological and geomorphological heritage, together with the historical, cultural and religious heritage,

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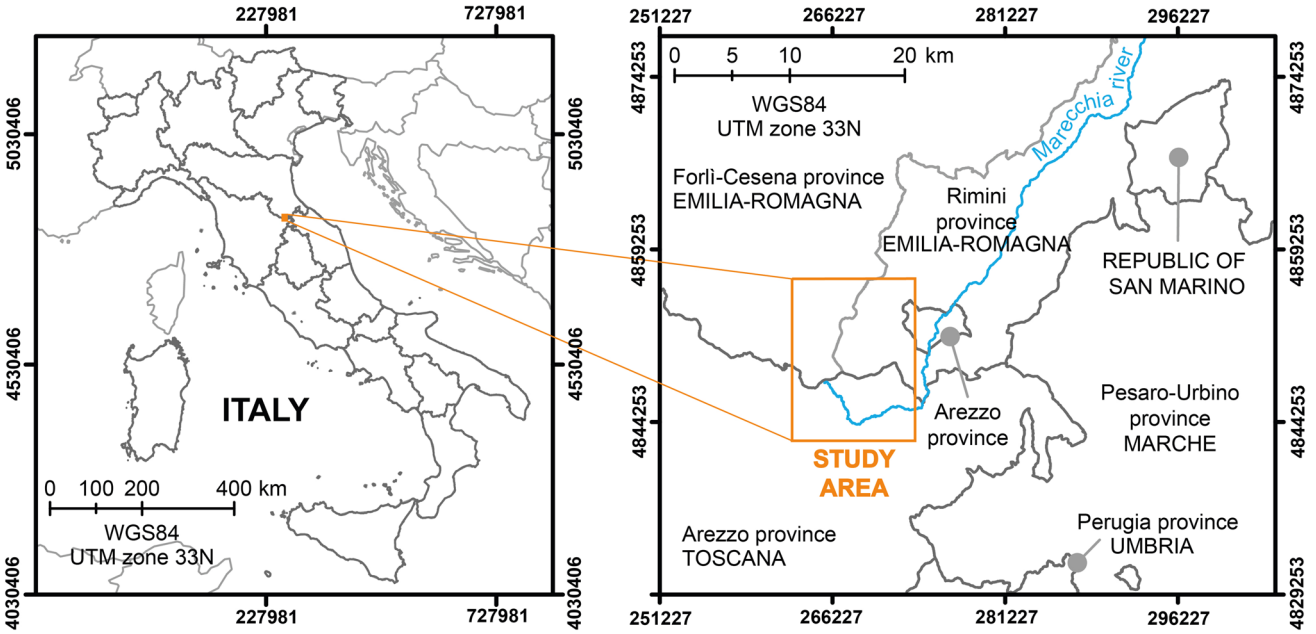

Fig. 1 Geographic location of the study area

produces a complex cultural landscape sometimes expressed through monumental and massive examples, and other times through hidden or invisible points of interest, which have the potential to bring visitors into a journey through time. The landscape is impressive, and together with the important historical and cultural values, it will indeed represent a key aspect of the visitors' experience.

The study area includes three protected sites (SIC-ZSC IT4080015 Castel di Colorìo, Alto Tevere; SIC-ZSC IT4080008 Balze di Verghereto, Monte Fumaiolo, Ripa della Moia; SIC-ZSC IT5180006 Alta Valle del Tevere) and many geosites have been established in the area by Emilia-Romagna region (Fig. 2).

Cultural Values of Geosites

Monumental landforms could be key sites to enhance geoheritage values through natural geoheritage, focusing on geotourism activities and proposals. From a cultural heritage point of view, the monumental landforms could indeed serve as a canvas to express geological complexity at different scales, thus resulting in engaging the viewer not only from a notional point of view but also involving the sense of wonder that those landforms induce, such as the case of the massive cliffs that lean out over Balze village, or the vertical layers outcropping in between Mt. Faggiola Vecchia and Mt. Faggiola Nuova.

Balze di Verghereto village is located at the foot of Mt. Fumaiolo, in Forlì-Cesena province (Emilia-Romagna region), close to Toscana and Marche region boundaries, in a scarcely populated territory of the Northern Apennines (Fig. 2). Balze toponym probably derives from *balzo*, which means *jump* and represents the cliffs towering over the village (Fig. 3).

It is located in the higher portion of the Marecchia river valley, close to its springs. This area of the village and its surroundings embody the unique geological context we find in Valmarecchia, and the fact that the same valley has been serving as a communication route since before roman times has enriched it with numerous historical and cultural aspects. That happened because of favourable conditions given by the Via Maggio mountain pass, close to the river springs, one of the lowest passes of this Apennine area. It was, in fact, easier to cross and remained accessible in the winter months. Travellers from northern Italy (and Europe) could use the *Ariminensis* road that followed the Marecchia river from Rimini, on the Adriatic coast, to Arezzo (Toscana) through the Via Maggio pass, which leads to central and southern Italy. In Balze di Verghereto, there is a high potential for geotouristic fruition but low attention on the geological values of the site. In fact, the village is located inside the environmentally protected zone of Mt. Fumaiolo (SIC-ZPS IT4080008).

Balze village is also crossed by the San Francesco's route that goes from Rimini to la Verna and has been travelled not only by the Saint but also by most of the pilgrims that would go to la Verna sanctuary. In the Middle Ages, the land featured many castles and fortresses. Uguccione della Faggiola was a leader and soldier of fortune (Barbero 2013)

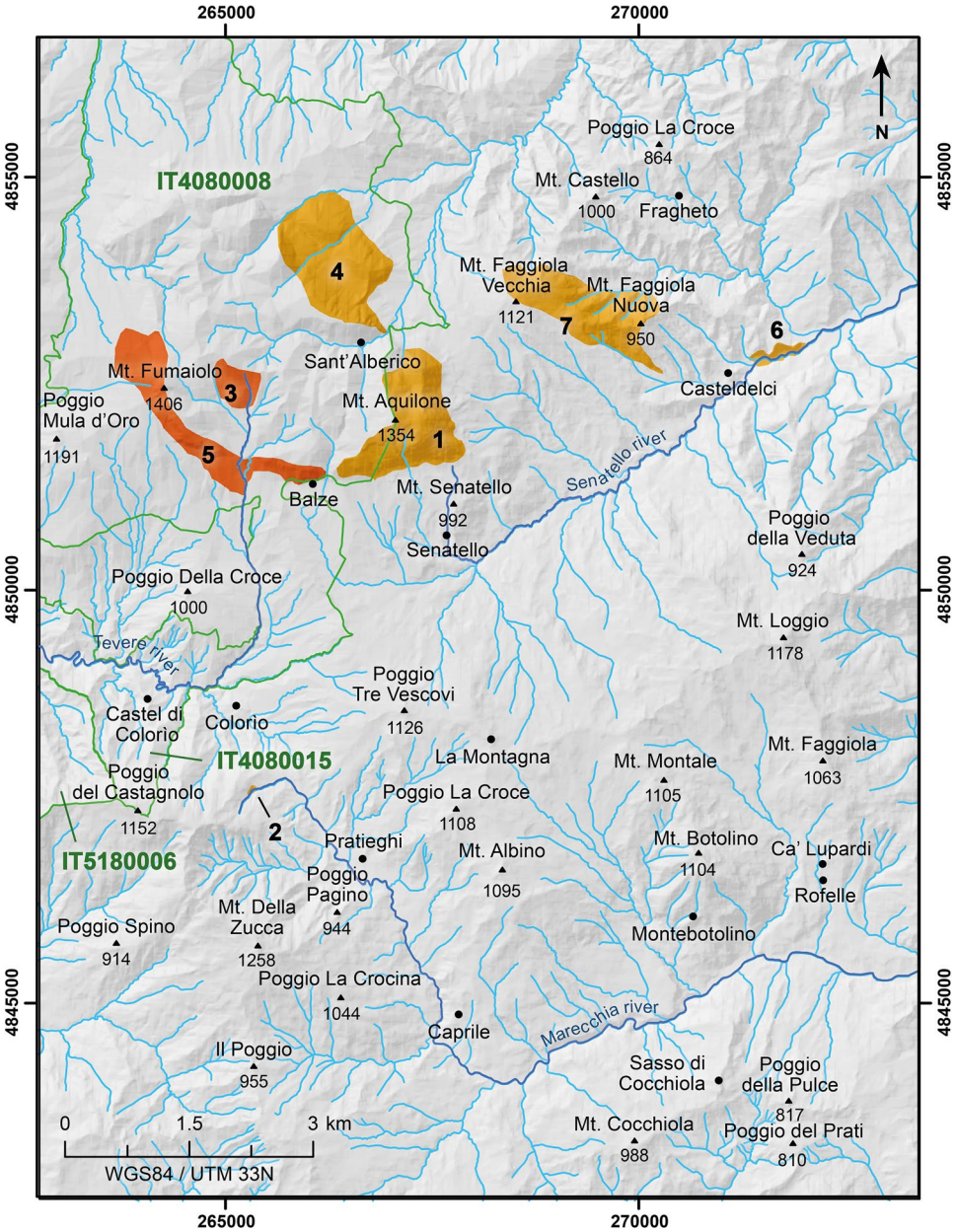

Fig. 2 Study area and protected zones

in the area, and some authors have found in him the *Veltro* that the poet Dante Alighieri was referring to in the Divina Commedia (Troya 1826, 1856; Balbo 1857). It is also possible that Dante was hosted in his castles when exiled from Florence (Dominici 1959).

At the time of Uguccione della Faggiola, there is also a legend associated with the Senatello springs: it is told that the running tears of a warrior, who received the pardon of God on a big rock in the proximity of the springs at the times of Uguccione della Faggiola, are still flowing and feeding the river.[1]

Not far from Balze village, another very important geosite is *Vene del Tevere* (=Tiber springs), the most abundant area of spring waters marked since the 1930s by a local travertine column overlooked by a golden eagle. Tiber and Marecchia springs geosites are both deeply linked to the ancient urban settlements of Rome and Rimini. According to an ancient Roman legend, the name Tiber derives from "Thybris" in memory of Tiberino Silvio, Aeneas' descendant (Moretti 2014), who died drowned in its waters. The Tiber has always been considered a historical watercourse, a river–museum.

Many other cultural sites express as hidden or invisible heritage, and they have been considered when quantitively assessing geoheritage value to the existing geosites. Other than impressive landforms, this area includes important cultural and

[1] From *La vena del Senatello e la sua leggenda*, an original document by Luigi Dominici (1930 ca.) viewed by courtesy of Luigi Mattei Gentili, direct descendant of the author.

Fig. 3 Monumental morphosculptures outcropping above Balze village, highlighted by a line drawing; in red: main fracture system; in black: stratification; in yellow: blocks prone to rock-falls due to the intersection amongst fracture systems

historical values that seem not at all additional to the geological ones in terms of the popularisation of the territory. Mt. Fumaiolo, characterised by several natural springs, has also been recently led back to the background of la Gioconda (Borchia and Nesci 2012), where a complex landscape has been represented by Leonardo. Their study states that the right part of the background represents the Marecchia river valley and the massif of Mt. Fumaiolo.

Moving south from Balze village, we find another massive mountain ridge named Alpe della Luna, which hosted many fights during World War Two (WWII hereafter). The Gothic Line passed near the massif, and nowadays there is an association that guides tours through the *Historical Park of the Gothic Line of Badia Tedalda* (http://www.parcostoricolineagotica.it/en/), thus contributing to an interdisciplinary approach on the fruition of the sites. Last but not least, the Tiber river springs are located in the Mt. Fumaiolo area and have been of fundamental importance in managing the whole Tiberina valley.

Geological Setting

Mt. Fumaiolo represents the highest peak (1406 m a.s.l.) amongst a restricted mountainous complex that extends for approximately 12 km^2 in correspondence of the administrative boundary amongst Toscana, Emilia-Romagna and Marche regions. This complex belongs to the Apennine relief system that constitutes the watershed line between the Tyrrhenian and Adriatic sides of the chain (Casagli 1994). The watershed line presents a clear deviation from the general SE-NW orientation that Lotti (2015) ascribed to a capture phenomenon carried out by the Tiber river with regards to the Adriatic rivers (Marecchia and Savio rivers). Mt. Fumaiolo complex fits into the outcropping Ligurian Units that fill up the San Piero in Bagno syncline (Casagli 1994).

The test areas are characterised by extended outcrops of massive allochthonous thrust sheets (known as Valmarecchia Nappe); they consist of Ligurian and Epiligurian Formations that overthrust the Umbro-Marchean autochthonous Units, drawing a peculiar landscape characterised by high geodiversity and marked above all by differential erosional landforms cut in various formations (Conti 1990, 1995; Conti et al. 2016; De Feyter 1991; Bonciani et al. 2007; D'Errico et al. 2014; De Capoa et al. 2015 and references therein). The Valmarecchia Nappe has been widely studied due to its complexity and interesting geological features (Bonarelli 1929; Capozzi et al. 1991; De Donatis 1992; Cerrina Feroni et al. 1997, 2002; Conti et al. 1987; Ricci Lucchi 1986; Selli 1954; Vai and Castellarin 1992; Zattin et al. 2002; Carmignani et al. 2004; Carmignani et al. 2013; Cornamusini et al. 2012).

The Ligurian and Epiligurian formations deposited in different sub-basins have been translated through a structural depression, the "Marecchia line" (Conti 1990), orthogonally to the main Apennine tectonic features. The

Ligurian Units, characterised by Cretaceous argillitic clays, are the principal rocks responsible for translating the formations above them, providing a preferential detachment zone to the migration that occurred during the Miocene uplift of the Apennine chain. Ligurian formations outcrop with the Villa a Radda, Sillano, Argille Varicolori and Monte Morello formations, whilst the autochthonous substrate is expressed by Marnoso-Arenacea, San Paolo marls, Verghereto marls, Villore Varicolored clays and Vicchio formations.

San Marino and Mt. Fumaiolo Epiligurian formations (Mt. Fumaiolo mountain range) are represented by shallower water sediments deposited during the movement towards the Adriatic front, such as limestones and calcarenites.

Cornamusini et al. (2017) proposed a complex mechanism for the emplacement of the Valmarecchia Nappe, which includes a tectonic origin due to the Mt. Nero Thrust and a submarine gravitational sliding development within the foredeep basin.

Quaternary deposits are represented by alluvial fans and terraced fluvial deposits (braided streams facies) of Ravenna Subsynthem (upper Pleistocene-Holocene) and Modena Unit (Holocene).

Therefore, the geodiversity of this area is induced by the different outcropping lithotypes, characterised by different behaviour to deformation and weathering.

In Fig. 4, the geological map of the study area has been redrawn and slightly modified from Conti et al. (2020); the illustrated geological symbology refers to the following geological domains, described in chronological order from oldest to most recent:

1. External Ligurian Domain (outer succession)
   - ELel—helminthoides flysch: limestones, marly limestones, marlstones and shales: Monte Morello formation (Eocene: Ypresian–Lutetian).
   - ELvr—varicoloured shales, siltstones, limestones, carbonatic sandstones, conglomerates and breccias: Sillano formation (Albian–Ypresian); Villa a Radda formation (Late Cretaceous–Early Eocene); Argille Varicolori formation (Early Cretaceous–Eocene_ Ypresian).

2. Epiligurian succession (pre-evaporitic)
   - EPbs sandstones, calcarenites, claystones, conglomerates, breccias and olistostromes: Monte Fumaiolo formation, Monte Aquilone member, della Vetta member (Miocene: Late Burdigalian–Serravallian); San Marino formation (Miocene: Late Burdigalian–Early Langhian).
   - EPra turbidite sandstones, marlstones, shales and breccias: Complesso della Valle del Savio (Middle Eocene–Late Oligocene).

3. Cervarola-Falterona succession
   - CFvc—marlstones, silty marlstones and siltstones, with interbedded sandstones: Vicchio formation (Miocene: Late Aquitanian–Langhian).

4. CFfa—turbidite sandstones, siltstones, shales and marlstones, with olistostromes: Verghereto Marls (Miocene:Aquitanian–Burdigalian); Villore Varicolored Marls (Eocene: Rupelian–Miocene:Aquitanian). Siliciclastic succession of the inner basin.
   - UMgh mudstones with olistostromes, channelled sandstones: San Paolo marls (Late Serravallian–Middle Tortonian).
   - UMma turbiditic sandstones and siltstones, with interbedded marlstones, calcarenites and hybrid sandstones: Marnoso-Arenacea formation (Late Burdigalian–Early Tortonian)

5. Quaternary continental deposits
   - Qa1 alluvial fan and terraced deposits: Ravenna Subsynthem (Late Pleistocene–Holocene); Modena Unit (fourth–sixth century AD–present day).

Methodology

In this work, geoheritage investigations have been based on a geomorphological reading of the territory and the analysis of landforms. Geomorphological investigations have been made by means of field surveys supported by multi-temporal aerial photos analysis and brought to compile the *Geomorphological map*, according to the indications of ISPRA's guidelines for geomorphological mapping (Campobasso et al. 2018). Then, the inventory of geosites and the quantitative assessment of the scientific and additional values have been conducted. Each geosite has been newly investigated to better relate the embodied values and express suggestions about management and conservation strategies. Geotouristic trails have been proposed in a *Geoheritage map*, distinguished by colour based on the main features that can be found on the trek.

Mapping has gained a high level of attention in geoheritage research (Regolini-Bissig and Reynard 2010; Fuertes-Gutiérrez and Fernández-Martínez 2012; Comănescu et al. 2013, 2017; Zwoliński et al. 2018; Bouzekraoui et al. 2018), and geomorphological mapping can represent a valuable tool in interpreting the values

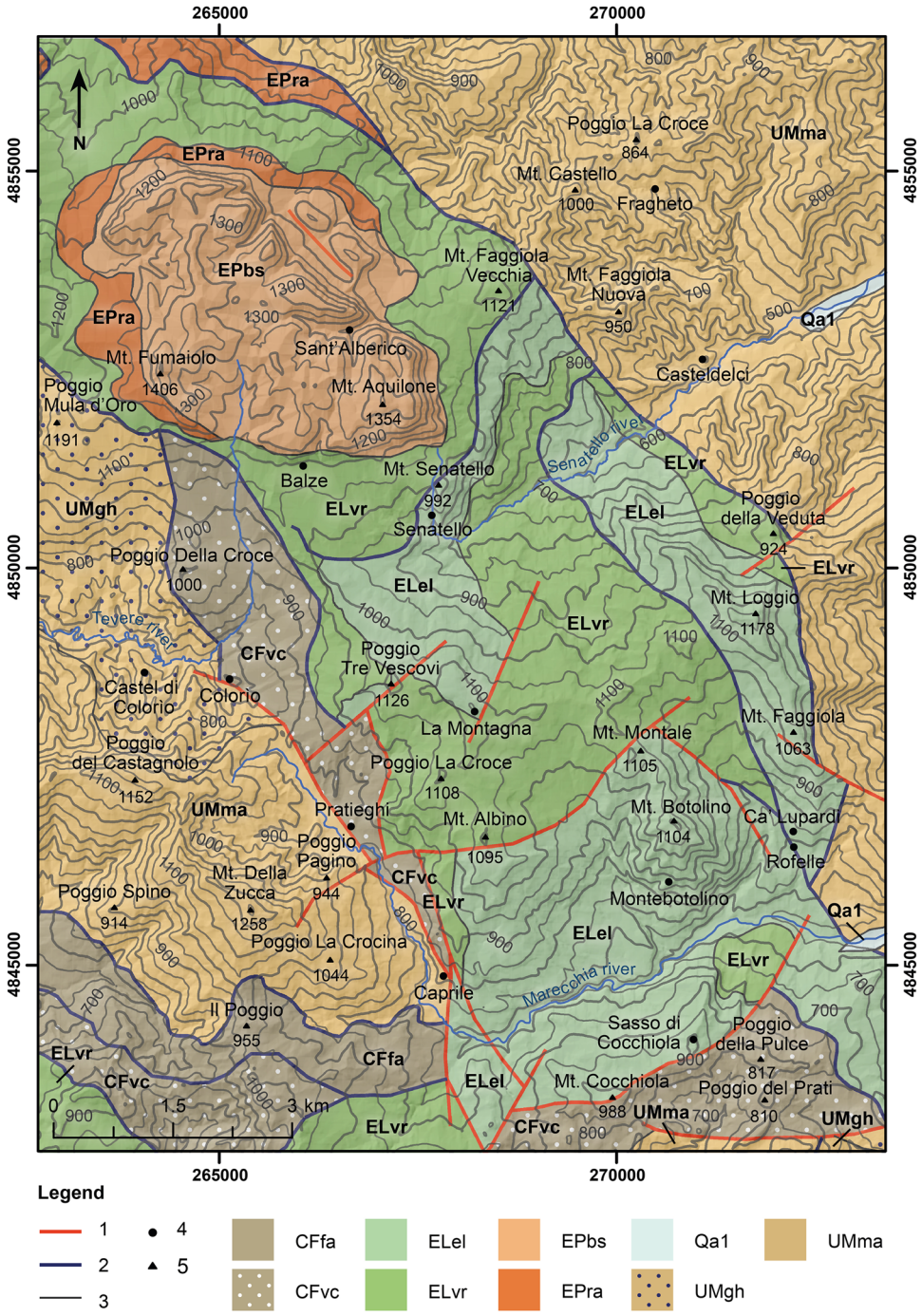

Fig. 4 Geological map of the study area, redrawn from Conti et al. (2020), coordinate system WGS84, UTM 33 N. Legend: 1 faults; 2 tectonic contrasts between main tectonic units, thrusts, low-angle normal faults; 3 stratigraphic boundaries; 4 main localities; 5 mountain peaks; geological main successions: Cervarola-Falterona succession: CFfa turbidite sandstones, siltstones, shales and marlstones, with olistostromes; CFvc marlstones, silty marlstones and siltstones, with interbedded sandstones. External Ligurian Domain (outer succession): ELel helminthoides flysch: limestones, marly limestones, marlstones, shales; ELvr varicoloured shales, siltstones, limestones, carbonatic sandstones, conglomerates and breccias Epiligurian succession (pre-evaporitic): EPbs sandstones, calcarenites, claystones, conglomerates, breccias and olistostromes; EPra turbidite sandstones, marlstones, shales, breccias. Quaternary continental deposits: Qa1 alluvial fan and terraced deposits. Siliciclastic succession of the inner basin: UMgh mudstones with olistostromes, channelled sandstones; UMma turbiditic sandstones and siltstones, with interbedded marlstones, calcarenites and hybrid sandstones

embedded in the geological landscape in relation to human development through time, thus delivering a full view of the landscape composition and evolution (Knight et al. 2011; Verstappen 2011; Otto and Smith 2013). Given these premises, the geomorphological map of the study area has been produced as the first step of the methodology adopted (Fig. 4); field surveys were carried out, supported by a multi-temporal analysis of aerial photos and bibliographical research. The geomorphological data have been georeferenced using the ArcGIS tool and overlapped with the geological map (Fig. 4, redrawn from Conti et al. 2020) and the available geological and regional geomorphological cartographies (Emilia-Romagna and Toscana regions) (Fig. 5) to compile the Geomorphological map of the study area (Fig. 6). The hydrographic network has been vectorised after comparing aerial images with the IGM Topographic Map of Italy (scale 1:25,000). The DEM used as a base is freely available as a 10-m cell size grid (in GeoTIFF format) in the UTM WGS 84 zone 32 projection system (Tarquini et al. 2007).

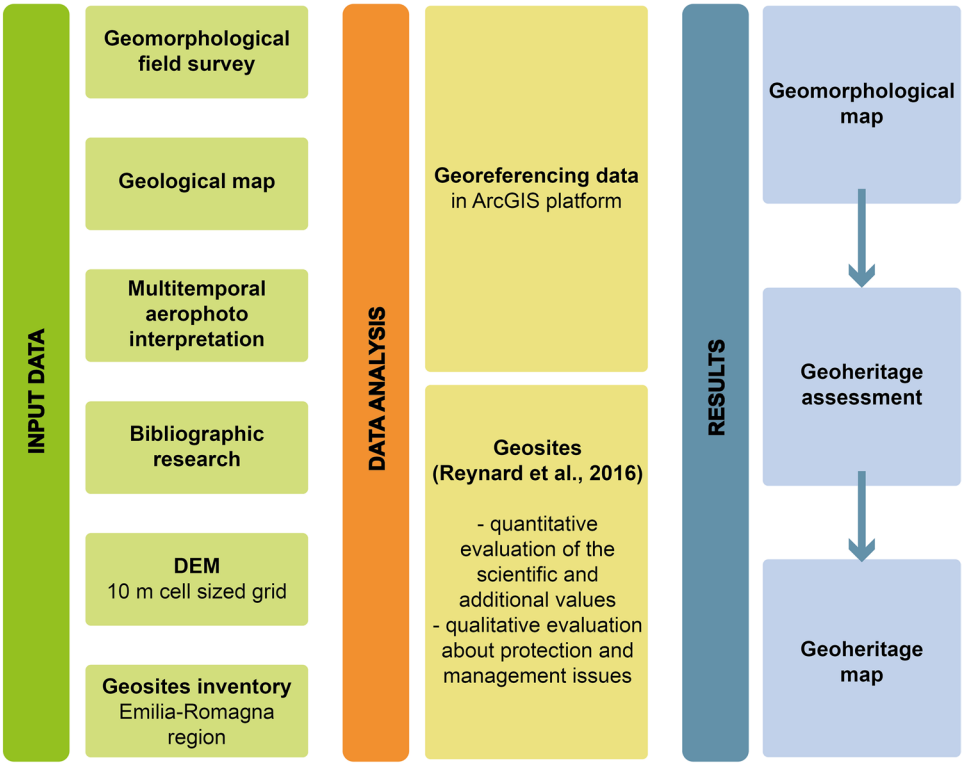

Fig. 5 Research methodology flow chart

The mapped landforms include stream terraces of the Marecchia, Senatello and Tiber rivers; flatirons, badlands and mudflows on argillitic and marly formations and rock falls on the boundaries of the main reliefs.

The scientific and additional values of the geosites were analysed through a Geoheritage assessment, a topic largely discussed over the last decades in scientific literature, where several qualitative and quantitative methodologies for assessing geosites and geomorphosites have been proposed (e.g., Reynard et al. 2016; Mucivuna et al. 2019).

The geological and geomorphological heritage of the area has been inventoried starting from the already catalogued geosites of the Emilia-Romagna region, implemented with geological didactic points of interest, and with the assessment of the sites' value, according to an adapted version of Reynard et al. (2016).

A representative code has been assigned to each geosites, composed of the first three capital letters referring to the study area (VMU = Upper Valmarecchia), the following three letters relating to the main process or represented geotype (flv = fluvial, tec = tectonics, mmv = mass movements, str = stratigraphy) and finally a progressive number associated to the process (Table 1).

The quantitative assessment for the geosites (adopted from Reynard et al. 2007 and 2016) was conducted regarding the following values:

- Scientific Value (Table 2, SV): assessment of criteria IN (Integrity), RE (representativeness), RA (rareness), PI (paleogeographic interest).
- Ecological Value (Table 3, EV): arithmetic mean amongst criteria EI (Ecological Impact), PS (Protected Site).
- Aesthetic Value (Table 3, AV): arithmetic mean amongst criteria VP (Viewpoints) and CVS (colour contrast, vertical development, space structuration).
- Cultural Value (Table 3, CV): highest score amongst RI (Religious Importance), HI (Historical Importance), AL (Artistic and Literary Importance), EC (Economic Importance).

According to the authors' observations, the values were attributed through a score from 0 to 1. The resulting scores have been summed for each geosite (Table 4) to get a quantitative expression of their comprehensive quality. The protection status of the geosites is expressed in Table 4, considering if they are comprised (entirely or partially) or not inside protected SIC-ZPS areas. Both *ongoing* and *needed* fields have been ticked in those cases where the geosites reside in a protected area, but more specific protection measurements are suggested. A qualitative evaluation of protection has also been compiled.

Finally, the natural landforms have then been associated with historical sites, cultural treks or religious places of interest through the Geoheritage map, produced after

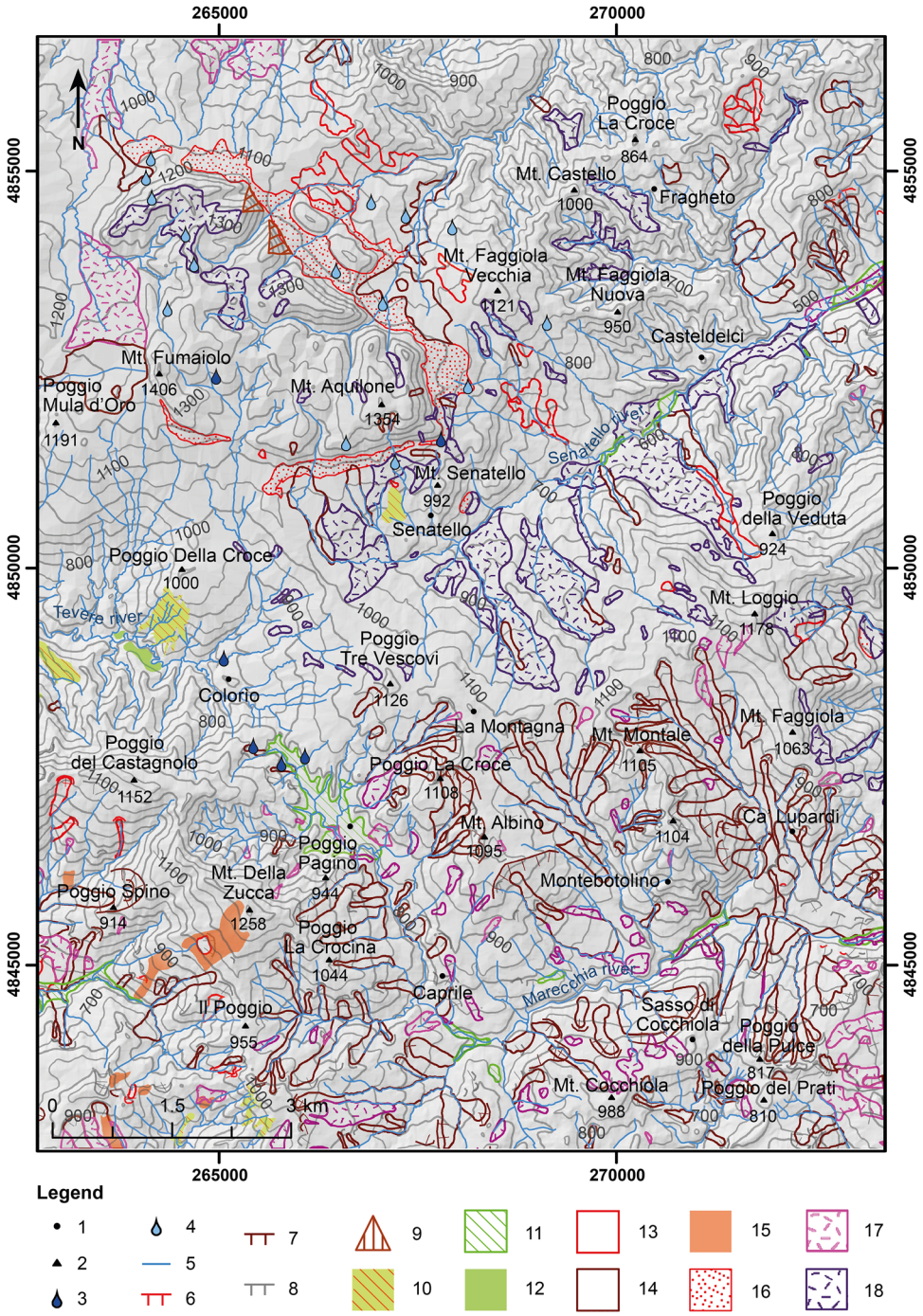

Fig. 6 Geomorphological map of the study area, coordinate system WGS84, UTM 33 N. 1 main localities; 2 mountain peaks; 3 natural spring with additional value; 4 natural spring; 5 hydrographic network; 6 landslide crown (active); 7 landslide crown (relict); 8 landslide crown (undetermined); 9 triangular fault facet; 10 badlands; 11 evolving fluvial deposits; 12 terraced fluvial deposits; 13 active landslide; 14 relict landslide; 15 areas of widespread landslides; 16 scree/talus deposits; 17 slope debris deposits; 18 eluvium-colluvial deposits

comparing the geomorphological and additional values of the sites through the quantitative assessment, implemented to set a relation amongst the natural components of the geoheritage of the valley and the cultural ones. Many features and objects, even if they are not purely geological, can, in fact, be interpreted as a part of the geological heritage (Wetzel 2002; Erikstad 2013; Gray 2013; Lubova et al. 2013; Bruno et al. 2014), which is true, especially, when archaeological sites are closely linked to the geological environment (Moroni 2015). Regarding these aspects, the Laughing stone, the bridges on Senatello and Marecchia river and the XXII places of fight have been mapped because they constitute an example of how geomorphology interacts with humanity.

Results

A *Geomorphological map* and a *Geoheritage map*, represented at a 1:75,000 scale, have been carried out to enhance peculiar landforms and processes and provide tools for

Table 1 General data of the geosite inventory

Nr	Code	Name	Location	Municipality	Coordinates/EPSG 32633		Altitude range/m a.s.l	Classification	Main features
1	VMUflv001	Senatello springs	Senatello springs, Mt. Aquilone	Casteldelci (RN)	267,226.092263	4,852,059.17847	1048–1353	Local relevance	Natural spring, pyramidal mount
2	VMUflv002	Marecchia springs	Badia Tedalda	Badia Tedalda (AR)	265,316.196954	4,847,605.95931	918–955	Local relevance	Natural spring, badlands
3	VMUflv003	Tiber springs	Mt. Fumaiolo pass	Verghereto (FC)	265,119.987870	4,852,519.71890	1186–1363	Regional relevance	Natural spring
4	VMUtec001	Sant'Alberico intra-mountain basin	Poggio l'Abetia, Pian del Brigo	Verghereto (FC)	266,304.205165	4,854,050.75742	1010–1310	Local relevance	Intra-mountain basin, deep-seated gravitational slope deformation
5	VMUmmv001	Mt. Fumaiolo relief	Balze, Mt. Fumaiolo	Verghereto (FC)	264,606.754600	4,852,118.84915	1060–1406	Regional relevance	Reference area, stratigraphic succession, rock buttress, mass movement
6	VMUstr001	Casteldelci cliff	Casteldelci, Ripa del Lamento	Casteldelci (RN)	271,675.237914	4,852,894.89966	489–630	Local relevance	Cliff, morphosculpture, stratigraphic succession
7	VMUstr002	Mt. Faggiola Vecchia and Mt. Faggiola Nuova reliefs	Casteldelci, Senatello	Casteldelci (RN)	269,368.793847	4,853,440.22543	655–1121	Local relevance	Fault, morphosculpture, bedform, stratigraphic succession

geotouristic fruition and the understanding of geological and geomorphological features of this northern Apennines portion. The regional inventory for the geosites has also been updated with new observations made on the site and by enhancing geomorphological points of interest. Finally, the geosites have been assessed with a quantitative evaluation of the scientific and additional values and a qualitative evaluation of protection and management issues.

Geomorphological Map

The lithological differences ensure an exceptionally wide variety of landforms. Limestones and calcarenites react with a fragile behaviour to structural deformation, producing rock-falls, toppling and rock pillars on the sides of the ridges. On the other hand, clays and marls produce gentle hills or badlands by the effects of linear erosion. Geomorphology also affected some toponyms in the area, such as

Table 2 Scientific value assessment

Geosite			Scientific value (SV)				
Nr	Code	Name	Integrity	Representativeness	Rareness	Paleogeographic interest	Average score
1	VMUflv001	Senatello springs	1	0.75	0.5	0.75	0.75
2	VMUflv002	Marecchia springs	1	1	0.5	0.75	0.81
3	VMUflv003	Tevere springs	1	1	0.5	0.75	0.81
4	VMUtec001	Sant'Alberico intra-mountain basin	1	0.5	0.75	1	0.81
5	VMUmmv001	Mt. Fumaiolo relief	1	1	1	0.75	0.94
6	VMUstr001	Casteldelci cliff	1	1	0.5	0.75	0.81
7	VMUstr002	Mt. Faggiola Vecchia and Mt. Faggiola Nuova reliefs	1	0.75	0.5	0.75	0.75

Table 3 Additional values assessment

Geosite			Ecological value (EV)			Aesthetic value (AV)			Cultural value (CV)				
Nr	Code	Name	EI	PS	EV	VP	CVS	AV	RI	HI	AL	Ec	CV
1	VMUflv001	Senatello springs	0.75	0.25	0.5	0	0.83	0.41	0	0	1	0	1
2	VMUflv002	Marecchia springs	0.75	0	0.37	0.25	0.5	0.37	0	1	0	0	1
3	VMUflv003	Tevere springs	0.75	1	0.87	0.5	0.58	0.54	0	1	0	0.5	1
4	VMUtec001	Sant'Alberico's intra-mountain basin	0.75	1	0.87	0.75	0.66	0.7	1	1	1	0.25	1
5	VMUmmv001	Mt. Fumaiolo relief	1	1	1	1	1	1	0	1	0	0.25	1
6	VMUstr001	Casteldelci cliff	1	0	0.5	1	0.92	0.96	0	0	0	0	0
7	VMUstr002	Mt. Faggiola Vecchia and Mt. Faggiola Nuova reliefs	0.75	0	0.37	1	0.75	0.87	0	1	1	0	1

Table 4 Summary table

SV	EV	AV	CV	Total score	Protection status			
					On going		Needed	Not needed
0.75	0.5	0.41	1	2.66	x	x		
0.81	0.37	0.37	1	2.55		x		
0.81	0.87	0.54	1	3.22	x			
0.81	0.87	0.7	1	3.38	x			
0.94	1	1	1	3.94	x			
0.81	0.5	0.96	0	2.27				x
0.75	0.37	0.87	1	2.99		x		

in the localities Balze and Sassoni (meaning *jump* and *big stone blocks*, respectively).

The geomorphological map outlines the main landforms of the study area (Fig. 6). This map includes active and inactive landslides and detachment crowns, the hydrographic network, stream terraces and badlands, deriving from the geomorphological database of the Toscana Region and the data of the Emilia-Romagna Region but partially revised in this work.

Regarding the relationship between lithotypes and slope processes, the argillitic and marly lithotypes deposits of the Argille Varicolori, Marne di Vicchio and Sillano (SIL) formations favour the development of the typical linear erosional landforms (badlands), differential erosional slopes, mudflows and debris-flows triggering. On the other hand, the areas where Monte Morello (MLL) formation outcrops are often affected by solifluction, deep-seated gravitational slope deformations and rock-slides (active or relict). These phenomena have been observed in the field and are reported in Fig. 6, where of interest and according to the selected scale. Rock-falls and complex landslides characterise the arenaceous lithotypes, limestone and cemented conglomerates, such as the San Marino or Monte Fumaiolo formations, with the development of the main ridges, vertical cliffs and rock pillars (Fig. 7). Rock-falls and topplings in those formations have also occurred in the past, above all during the last glacial period and in more recent times (i.e. Little Ice Age, Fagan 2001). In fact, in the Romagna-Marche area, there have been several cold phases in recent historical times, with a consequent increase in the diffusion and severity of hydrogeological instability phenomena (Guerra and Nesci 2013).

Fluvial morphologies are characterised by braided channels according to hydraulic parameters related to the riverbed slopes (Pizzuto 2011).

Geosite Inventory

The following geosite inventory was partly based on existing ones, established by the Emilia-Romagna region and instituted with the Regional Law No 9/2006. Moreover, a part of the study area that comprises some of the geosites was popularised by the region through a geothematic map, named "Geo-environmental itinerary in the Marecchia Valley—discovering Valmarecchia, geodiversity and a unique geological landscape in Romagna", presented in 2015 and freely available at the source https://ambiente.regione.emilia-romagna.it/it/geologia/geologia/geositi-paesaggio-geologico/itinerari/Itinerari-valle-Marecchia/, from which the Uguccione trail has been inspired.

Fig. 7 Geosites and points of interest examples: **a** Sassoni locality; **b** monumental landforms near Balze village; **c** surface karst evidences and Senatello springs (VMUflv001); **d** monumental landforms near Balze village; **e** Balze cliff

1. *Senatello springs* (VMUflv001)—this geosite encloses the areas of Mt. Aquilone and Poggio del Passino reliefs, from which the Senatello river springs. The water source is enclosed by a capture work dating back to 1920 that initially diverted the flow towards the Savio valley, whilst today it supplies the residencies of the Senatello valley. A small fountain is located underneath the road next to the catchment and a short distance away is the "overflow" of the spring, consisting of a copious outflow that testifies the extraordinary flow of the water veins. The spring is situated at the base of the southern slope of Mt. Aquilone, at the geological contact between the rocks that constitute Mt. Aquilone and the clayey Ligurian units that lie below. Mt. Aquilone is in fact composed of the limestones of San Marino formation, topped by the sandstones of Mt. Fumaiolo formation (Conti 1989), both made highly permeable by a dense network of fractures and resting on the impermeable clayey rocks of the Ligurian units (Villa a Radda and Monte Morello formations). The fractured limestone acts as a large storehouse of water, where filtration leads to the formation of an aquifer in contact with the impermeable Ligurian clays. Intercepted by the surface, this contact returns the spring water. The entire mountain complex between Mt. Aquilone and Mt. Fumaiolo is characterised by this geological structure and is very rich in water and thus water springs.

2. *Marecchia springs* (VMUflv002)—the springs of the Marecchia river are located at 1263 m a.s.l. in Forconaia locality (Pratieghi, Arezzo province, Toscana), along a valley that deepens on the eastern side of Poggio Castagnolo, at a short distance from the top of Mt. della Zucca, a mountainous complex formed by the Marnoso-Arenacea formation and covered by beech trees (Albini 2012). The Marecchia is a torrential river that collects the waters from the Viamaggio watershed (Castello di Ranco locality). When rising the Marecchia valley, close to the main Apennine ridge, it is possible to find the confluence of two branches of water of similar value: the Presale creek, which originates at the foot of the Alpe della Luna ridge, heading south, and the Marecchia river, whose course bends westwards into a wide head, beyond which the upper Tiber valley opens up. Along this watershed, the landscape allows grasping the different rocky units. The marly rocks of the Vicchio formation (De Donatis 1992), light grey in colour, are immediately evident and exposed in the gully incisions that interrupt the meadows and become badlands. Here, vegetation is fragile; the juniper is a sign of poorly evolved and difficult to colonise soil; black pine reforestations are evident on the margins and constitute an exotic species that has been used in historic times to stabilise the slopes with little soil thickness. The ridge from which Poggio Tre Vescovi rises and the surrounding areas are characterised by the outcropping of Ligurian units of

the Valmarecchia nappe. Access to the site is of medium difficulty.

3. *Tiber springs* (VMUflv003)—the Tiber river originates from two spring areas (Di Matteo et al. 2017; Maccari 2005) located along the northern slope of Mount Fumaiolo, known in past times as Fiumaiolo (from Italian word *fiume*, meaning river), at 1268 m a.s.l.
4. *Sant'Alberico intra-mountain basin* (VMUtec001)—Sant'Alberico intra-mountain basin is located at the bottom of a large trench in the NE slopes of Mt. Fumaiolo, elongated in a SW-NE direction and enclosed between slopes formed by the limestone of San Marino formation (Conti et al. 2016). This sub-flat area was called *La Cella di Sant'Alberico* (= St. Alberico's cell) in ancient maps, and *Cella* in the toponymy of CTR maps. It is located at the bottom of a tectonic trench 700–800 m wide and extended in the SW-NE direction for more than 4 km, enclosed between the steep wooded slopes of Pian del Brigo and Croce della Costa to the South, and by pyramidal reliefs, including Poggio l'Abetia. The Pietricci ditch flows into the intra-mountain basin to the south, without exit, whilst in the same direction (along the same fault line?), the Parella ditch comes out of the plain. The reliefs are formed by limestones of the San Marino formation (biocalcarenitic member of San Alberico formation) and by the sandstones of Mt. Fumaiolo formation. These units rest on the Melange of the Savio Valley. Saint Alberico's Hermitage and La Cella points of interest (R1 and R2) are located in the area of the geosite. Accessibility to the site is easy.
5. *Mt. Fumaiolo relief* (VMUmmv001)—extensive rocky buttress along which sandstones of Mt. Fumaiolo formation outcrop on the western and southern slopes, where it constitutes the reference area for the formation (Amorosi 1992; Conti 1989; De Capoa et al. 2015). One can observe the passage to the San Marino formation along the southernmost wall. Towards NO, large boulders mobilised by the rock-debris layer mark the surface of a landslide. In the area known as I Sassoni (= big stone blocks), large rocky boulders are located on the surface of the slope, below the rocky outcrop. These large blocks fell from the cliff and were originally part of the detritus layer mobilised at the head of an active and quiescent landslide, characterised by a complex movement developed in the clayey units below. The toponym Fumaiolo can derive Fiumaiolo (from *fiume*, meaning river) for the conspicuous springs (Maccari 2005; Di Matteo et al. 2016; 2017) that flow along and around its slopes. Natural caves existing in the area have been registered in the Cadastre of natural cavities of the Emilia-Romagna region.[2] They have been included in the map, although public access to natural cavities is generally forbidden and always subject to specific regulation. The two caves are named Buca del Diavolo di Verghereto[3] and Pozzo della Briglia di S. Alberigo.[4] Accessibility to the site is easy.
6. *Casteldelci cliff* (VMUstr001)—the Marnoso-Arenacea Formation (Capozzi et al. 1991; Bonciani et al. 2007; De Capoa et al. 2015) emerges along the left bank of the Senatello river with excellent exposure, showing an almost perfectly horizontal stratification. The Marnoso-Arenacea formation is expressed here as the Member of the Hill, a pelitic-arenaceous lithofacies marked by intercalation of sandstones in thin and medium beds, at times thick and thick, with an A/P ratio of less than 1/5, and shows a sub-horizontal layering of the stratification. Morphosculptures mark the outcrop due to erosive selection of the arenaceous and marly layers, which created a stairway between the base and the top of the Ripa, called *Ripa del Lamento* (= Cliff of Lamentation) in the local tongue. Direct access to the site is difficult, but it is possible to have a clear view of the cliff from the main road system.
7. *Mt. Faggiola Vecchia and Mt. Faggiola Nuova reliefs* (VMUstr002)—along the ridge between Mt. Faggiola Vecchia and Mt. Faggiola Nuova, the geometrical relationships between the Valmarecchia nappe and the rocks on which it has been placed during orogenesis, constituted here of the Marnoso-Arenacea formation, can be observed in an exemplary manner (Conti 1989). All the geological units involved show very intense deformations, appreciable from different perspective points. In the area, the layers of Marnoso-Arenacea formation show evident changes in their position, drawing a particular synclinal fold, which develops close to the tectonic contact (a relaxing fault) between the blanket and the Marnoso-Arenacea. In the area surrounding Mt. Faggiola Nuova, the landscape presents clear changes in morphology and plant cover, drawing neat passages between wide areas marked by soft morphologies and covered by grasslands and much steeper slopes covered by woodland. Moving towards the summit, it is possible to walk on the contact between the Ligurian Units and the Marnoso-Arenacea formation, which presents itself with the upturned stratification, immerging towards the west. Going along the ridge in the direction of Mt. Faggiola Nuova, one can walk on the verticalised layers of the Marnoso-Arenacea formation with the possibility of observing a didactic example of selective erosion: the softer marly layers are more easily eroded by weather-

[2] https://geo.regione.emilia-romagna.it/cartografia_sgss/user/viewer.jsp?service=grotte

[3] https://geo.regione.emilia-romagna.it/schede/speleo/index.jsp?id=34078

[4] https://geo.regione.emilia-romagna.it/schede/speleo/index.jsp?id=34079

ing, whilst the arenaceous ones, much more tenacious, form protruding cornices moulded into aligned pinnacles that produce the typical sawtooth morphologies. Access to the site is of medium difficulty.

Moreover, a series of additional geological points of interest have been investigated and highlighted in the Geoheritage map to enable visitors to find specific sites representing the values embedded in the different geosites or other peculiarities. The points have been distinguished through a code that expresses their Geological value (G1, G2…), Historical value (H1, H2…, or WW1, WW2… for the XX century historical sites) or Religious value (R1, R2).

Geological points of interest are the following:

- *Intra-mountain structural basin* (G1) – the point of interest is located at the bottom of the large sub-flat tectonic trench area on Mt. Fumaiolo, elongated in a SW-NE direction for more than 4 km, enclosed between the slopes formed by limestones of San Marino formation.
- *Pozzo della Briglia di Sant'Alberico* (G2) and *Buca del Diavolo di Verghereto* (G6) are the two caves registered in the Cadastre of natural cavities of Emilia-Romagna region.
- *Sassoni* (G3, = big stone blocks) is a locality in the proximities of Mt. Fumaiolo, possibly named after the presence of massive boulders (Repetti 1841), detached from the massif above because of important rock-falls.
- *Tiber waterfalls* (G4) site shows a typical example of how those landforms represent the extreme manifestation of a knickpoint/channel gradient steepening (Goudie 2020).
- The toponym *Laghi* (G5), associated with *Fosso dei Laghi* (= lakes creek), a minor watercourse in the area, is possibly related to a sub-flat portion of the territory where lakes could have possibly existed in past times. It is found at 1210 m a.s.l. on the southern cliff of Mt. Fumaiolo, west of Balze village. This site indicates the possible location of a palaeo or archaeolake, whose formation should be related to the complex faults' system of Mount Fumaiolo formation calcareous banks in association with a high level of saturation of the aquifer. Borchia and Nesci (2012) also suggested a lake located in the proximities of Senatello spring, included in the landscape portraited by Leonardo da Vinci as a background for la Gioconda. This last lacustrine testimony should be related to the generalised tendency of accumulating precipitated rain and snow at the foot of the cliffs, which is a direct consequence of the geological setting of the outcropping lithotypes (argillitic clays lying underneath highly fractured calcareous massifs), and testimonies the evolving geomorphological features about different environmental conditions.
- *Balze* (G7) shows a didactic example of differential erosion on the massive outcrop towering over the village.
- *Surface karst evidences* (G8) occur most notably in the area located east of Balze village, where they are enhanced by vegetational patterns that highlight the main fractures of the boulders situated there.
- *Verticalized layers* (G9) inside a massive Marnoso-Arenacea formation outcrop, where the process of differential erosion stands out in the hillside, constituting a potential didactic geomorphosite, a place where to observe and touch by hand those geological phenomena that influenced today's landscape.
- The *Cliff of Lamentation* (G10) is a didactic outcropping that embodies geological and geomorphological concepts such as sedimentation processes, river cutting and past tectonics; the point is included in Casteldelci cliff (VMUstr001) geosite, which catches the visitor's attention with its impressing scenery. The outcrop emerges from the Senatello riverbed and shows the undeformed horizontal setting of the Marnoso Arenacea formation layers.
- *Santa Maria in Sasseto palaeosurface* (G11, 768 m a.s.l.) is a flat terrace on the Marecchia valley, a planation surface resulting from the subsequent erosive and denudation phases of the uplifted Apennine mountains during ancient stationing of the local base levels of erosion (Guerra and Lazzari 2020). Uplift and the emergence of the Apennines were accompanied by the progressive establishment of a dynamic equilibrium between erosion and deposition rates, also linked to the different climatic phases that have occurred over time (Cyr and Granger 2008). In addition, a Historical value has been associated with the site thanks to the discovery of artefacts that testify roman and mediaeval population of the site (see *Uguccione trail*).
- *Colorìo badlands* (G12) are located along the right side of the Tiber river, on Poggio della Croce mountainous slopes, and develop on arenitic-pelitic turbidites of the Marnoso Arenacea formation (Montecoronaro member), with an A/P ratio < 1/6. Arenites are finely stratified and consist of fine brownish sands, whilst the pelitic portions consist of grey marly siltstones. Visibility to the point of interest is optimal from Castello di Colorìo mountain hut, a former farmhouse that was part of the Faggiola's Castle of Colorìo. Two basement rooms and the cistern of the fortress are located on the small hill above the hut.
- The *Laughing stone* (G13) is a curious rock boulder isolated inside the woods, where a human profile has been

shaped by erosion. Honeycomb weathering is particularly developed and represents a rare case in the study area.

Historical points of interest include a bridge on the Senatello river, a ruinated bridge on the Marecchia river, ancient castle sites and several places of fight related to World War II. These last are due to the presence of the Gothic Line of Badia Tedalda in the southern portion of the study area. The highlighted Historical points of interest are the following: Faggiola Vecchia castle site (H1), Uguccione castle ruins (H2), Mediaeval bridge on the Senatello river (H3), Pescaia (H4), Le Ripe (H5), Colorìo castle ruins (H6), Roman bridge ruins on the Marecchia river (H7), Fragheto (WW1), Mt. Castagnolo military posts (WW2), Pratieghi (WW3), Mt. della Zucca military posts (WW4), Caprile military posts (WW5), Valdazze (WW6), Mt. Faggiola military posts (WW7), Mt. Botolino military posts (WW8), Rofelle (WW9) and Sasso di Cocchiola military posts (WW10).

Two Religious points of interest have been identified in the St. Alberico hermitage site (R1), still active today, that dates back approximately to the eleventh century AD, and La Cella (R2), known in past times as "Cella San Joannes *inter ambas Paras*". It is believed that St. Alberico hermitage was initially founded by Saint Romualdo, founder of the Camaldolese congregation, who lived in the tenth century. St. Alberico was presumably a hermit who followed St. Romualdo's teachings, although his life is scarcely documented and mainly linked to oral tradition. It is believed that Alberico built his first shelter as a cell and two caves inside the rocks, where he lived in penance and holiness, performing miracles and healing abdominal diseases and hernias.[5]

La Cella site hosts a monastery founded by St. Romualdo in the tenth century (Dominici 1959) in between Parella (NW) and Para creeks (SE, Savio river tributary), and this characteristic originated its ancient name "Cella San Joannes *inter ambas Paras*", meaning precisely *in between the Paras*. A water spring and a boulder located outside the hermitage are still considered thaumaturgical today in relation to the Saint. Both R1 and R2 sites are related to St. Francesco's journeys and have been frequented by him and many pilgrims.

A monumental beech tree is located near Saint Alberico hermitage (T1, Faggio di Sant'Alberico), as evidenced in the map and several other significant examples of the same species that gave the name to *Poggio Sette Faggi* (=hillock of the seven beeches, T2).

Historical watermills that can be found numerously in the Marecchia valley and mostly date back to the eighteenth and nineteenth centuries have also been highlighted.

[5] Source: http://www.fumaioloturismo.it/-/verghereto-eremo-di-sant-alberico-abbazie

Moreover, several water springs have been highlighted in the map, with a particular reference to the ones that convey associated additional values. The Tiber (S1) and Marecchia (S4) springs have an associated historical value as the major cities or respectively Rome and Rimini enjoyed favourable conditions for the human settlement due to the presence of the rivers. The Senatello spring (S2) has an associated cultural value due to the warrior's legend in oral and written traditions (see Senatello springs geosite description). A sulphurous spring (S3) is located in the proximities of the village of Colorìo and has an associated value due to the sulphur presence. Lastly, two more springs (S5 and S6) have been found thanks to historical written and oral testimonies and fieldwork and have been related to Dante's presence in these lands, well remembered by local tradition.

Dante's Higher and Lower Spring

A local tradition associates the village of Pratieghi with the passage of the poet Dante Alighieri. The inhabitants still say that Dante used to refresh himself in a nearby spring, as humble as those of the Marecchia river, not far from it. This spring had been identified in the 1950s in a site not far from the driveway, and road signs had been placed leading to it, with obvious tourist purposes. Today, only rusty fragments of those signs remain and are dislocated from their original location. This point has been highlighted as S6 (Fig. 8). Still, the position does not respect the one described by historical sources (Dominici 1959), which refer to it as being about halfway between Pratieghi and Colorìo Castle, not far from the source of the Marecchia river. Going up the stream from the lower spring, one comes to an area of long-stemmed trees cultivation, where minor creeks start accumulating precipitated water. Going further up towards the ridge, one encounters a very small vein of water, which seems to feed the streams, albeit sparsely. Dante's higher spring has been identified in this minor vein (S5, Fig. 8) as a possible location for the original water source.

It is reasonable to think that morphological modifications and lowering of the water table almost extinguish the spring. These sites, in particular, convey several values (geomorphological, hydrological, historical, cultural) that could be the starting point of a reflection about how to manage similar examples of geomorphosites, to get to an integrated valorisation of the natural sites that convey cultural and historical strong values.

Geosites Quantitative Assessment

Following the qualitative and quantitative methodology for assessing geomorphosites proposed by Reynard et al. (2016), it was possible to associate a score to each geosite for the Scientific value (Table 2), Ecological value (EV), Aesthetic

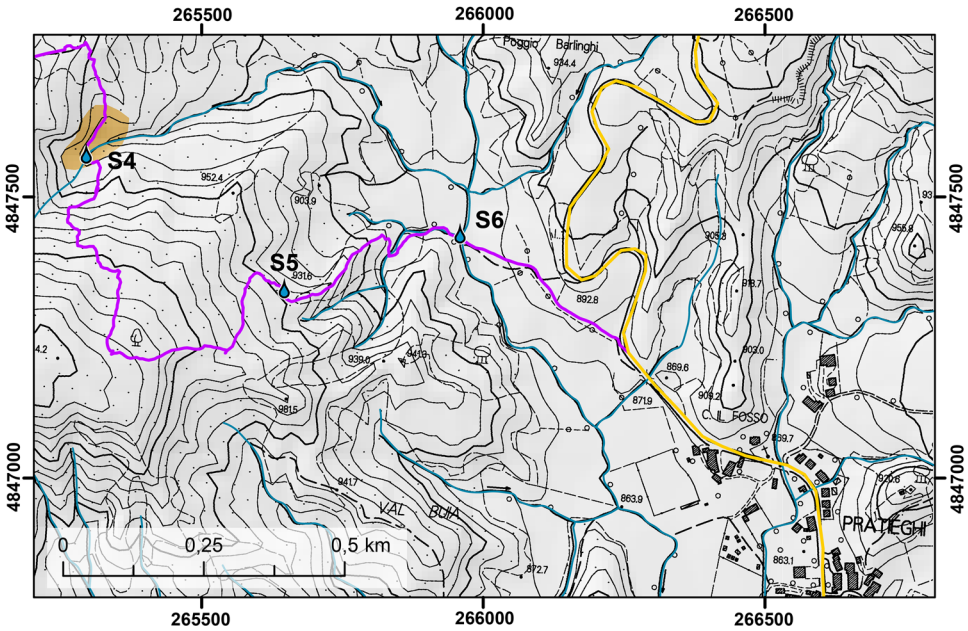

Fig. 8 Marecchia springs (S4) and Dante's higher (S5) and lower springs (S6) on Dante's trail, in the surroundings of Pratieghi village; coordinate system WGS84, UTM 33 N

value (AV) and Cultural value (CV), as summarised in Table 3, to verify the hierarchy of the total values of the geosites also according to their protection and conservation priority (Table 4).

For the scientific value assessment, all geosites have retained their integrity, with a score of 1 (Table 2). Their representativeness is high in relation to Valmarecchia Epiligurian units (average score of 0.87). Their rareness is of medium importance if related to the broader geological and geomorphological settings of the northern Apennines (average score 0.61). Also, the paleogeographic interest is high (average score 0.78), with a maximum score in the geosite of Sant'Alberico intra-mountain basin.

Ecological Impact (Table 3) is generally high due to the presence of protected species and xerophile environments in correspondence to calcareous peaks (average score 0.82). Protected Site values have been assigned as follows: 0 = no protection, 0.25 = a limited portion of the geosite resides in a protected area and 1 = all the extent of the geosite resides in a protected area. The Marecchia springs, Casteldelci cliff and Mt. Faggiola Vecchia and Mt. Faggiola nuova relief areas are not under protection, whilst Tiber springs, Sant'Alberico intra-mountain basin and Mt. Fumaiolo relief reside totally in protected areas. Senatello springs' geosites partially reside in a SIC-ZPS protected area, but the springs themselves are outside this portion. The average score of the PS criteria is 0.46.

Aesthetical Value (Table 3) is expressed as the criteria View Points and CVS (Colour contrast, Vertical development and Space structuration), which have medium–high mean values due to vertical cliffs, high altitude locations, limestones above clayey and marly lithotypes and have an average value of, respectively, 0.64 and 0.75.

Cultural Value (Table 3) is expressed with the criteria Religious Importance, Historical Importance, Artistic and Literary Importance and Economical Importance. Because the CV is defined not as an arithmetical mean but as the highest value amongst the criteria, all the geosites reach the score of 1 except Casteldelci cliff, in which no relevant cultural features have been detected. The EI of these geosites is negligible: few proper popularisation actions have been undertaken, and the area has not been enriched with any geotouristic panels; thus, the only income that comes from the geosites is provided by spontaneous fruition of the sites and visits at the historical localities nearby.

Geoheritage Map

We propose a Geoheritage map that conveys the geotouristic sites, such as geosites, geomorphosites and monumental landforms, and sites of additional value, like the historical, cultural and religious ones, through a series of trails distinguished by the value they convey (Fig. 8).

In the north-western part of the map, we can see Balze village, crossed by *San Francesco's trail* (n. 15 in the map), and starting point of the *Springs trail* (n. 17) (Fig. 9) that surrounds Mt. Fumaiolo and brings to Tiber's spring. In red, we have the *Uguccione* trail, where one can also find significant geological sites such as the *Cliff* of *Lamentation* (G10) and *Verticalised layers* in the Marnoso-Arenacea formation shaped by erosion (G9). Moving south on the San Francesco trail, we cross the *Dante trail* (n. 19) that overlooks the badlands of Colorìo (G12) and includes the ruins of Colorìo

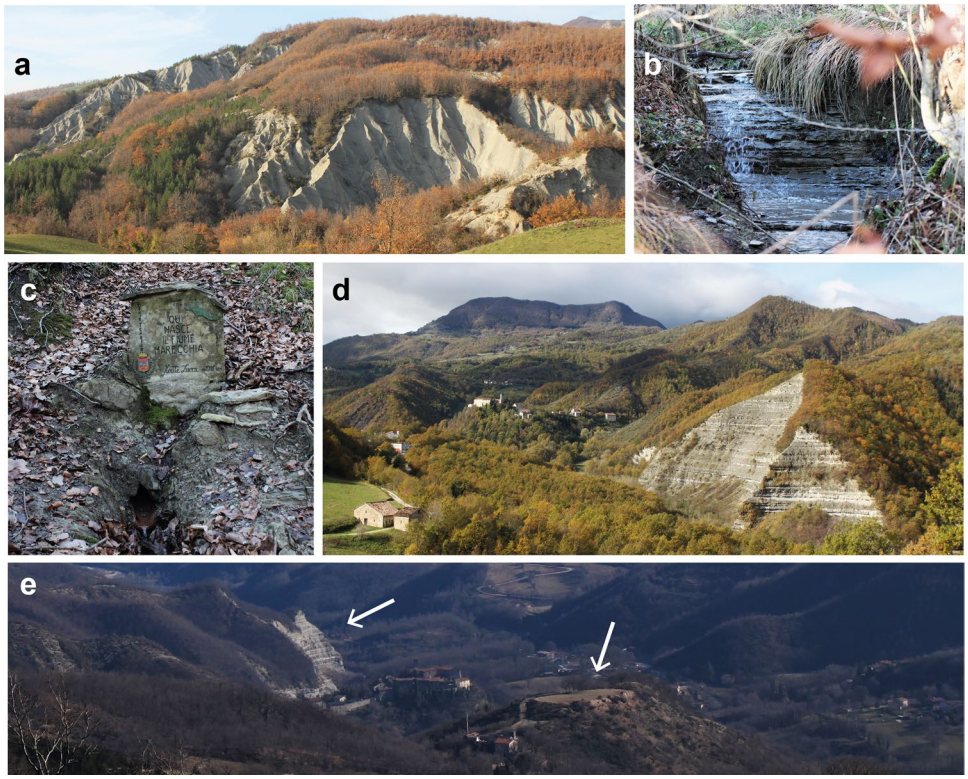

Fig. 9 Geosites and points of interest examples: **a** Colorìo badlands from Colorìo castle ruins; **b** Dante lower spring; **c** Marecchia springs geosite (VMUflv002); **d** Mt. Fumaiolo (VMUmmv001) and Casteldelci cliff (VMUstr001) geosites; **e** Casteldelci cliff (VMUstr001) and Santa Maria in Sasseto paleosurface

castle (H6), a curious calcarenite rock locally known as *the Laughing Stone* (G13), and the springs of Marecchia river (S4). Then we propose two trails towards WWII places of fight and a separate ring path that goes deeply into Gothic Line–related sites and includes the ruins of a Roman bridge upon the Marecchia river (H7) (Fig. 10).

Itineraries

Several itineraries have been mapped to allow visitors to reach the highlighted geosites and geological, historical and religious points of interest. Some of them are based on existing and well-signed trails, but some portions have been traced on more challenging paths that require a good level of trekking and orientation skills. For these reasons, this article should be considered a starting point for building tailor-made itineraries based on consulting appropriate trail maps and hiker portals.

- *St. Francesco trail* (n. 15) is part of a much longer trail named *San Francesco's trail from Rimini to La Verna* that goes from the Adriatic town to the Saint's sanctuary, located in Arezzo province. The trail is based on historical records or cultural evidences of the Saint's journey and has been recently developed with a touristic approach and receiving a positive response from local and national authorities.
- *Uguccione trail* (n. 16) enables visitors to relive the places and landscapes that the historic figure attended and shared with Dante by touching several geological and cultural points of interest such as the *Faggiola Vecchia castle site* (H1), *Verticalized layers* in the Marnoso-Arenacea formation (G9), *Uguccione castle ruins* on Mt. Faggiola Nuova (thirteenth to fifteenth century AD according to Sacco 2010, H2), *Cliff of Lamentation* (G10), Mulino del Rio, a *Mediaeval bridge* (named Ponte Vecchio, meaning *old bridge*, and built where a previous wooden bridge of roman age was located, H3) and the Molino di Castello in Casteldelci village, the site of the Roman necropolis of *Pescaia* (second to third century AD[6], H4) and the church of Santa Maria in Sasseto, attested since the twelfth century, rebuilt in the sixteenth century and restored in the nineteenth century; frescos inside the church have been dated back to 1559 and 1569.[6] The flat *Santa Maria in Sasseto palaeosurface* (G11) is a scenic point of view on the Senatello and Marecchia valley; the site of *Le Ripe* (=the cliffs, H5) stands out to the east and artefacts of the Iron age and roman age have been found (Ermeti and Sacco 2007).
- *Springs trail* (n. 17) crosses numerous Fumaiolo contact springs, originated from water accretion in permeable

[6] Source: TourER, web portal of Emilia-Romagna region cultural heritage. https://www.tourer.it/mappa?lang=en

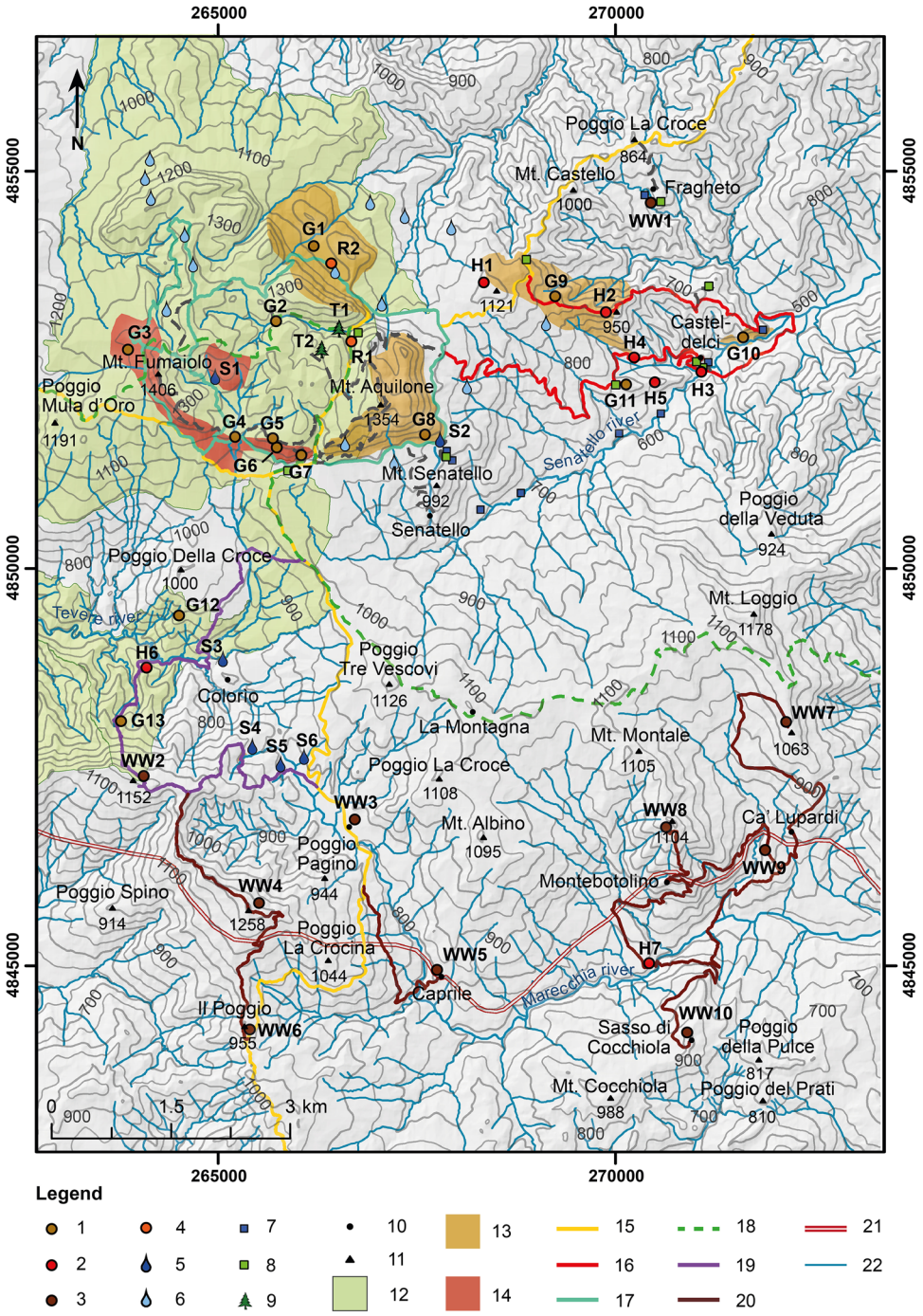

Fig. 10 Geoheritage map of the study area, coordinate system WGS84, UTM 33 N. 1 Geological point of interest; 2 Historical point of interest; 3 twentieth century point of interest; 4 Religious point of interest; 5 natural spring with additional value; 6 natural spring; 7 historical watermill; 8 TourER protected buildings; 9 monumental trees; 10 main localities; 11 mountain peaks; 12 SIC-ZPS protected areas; 13 Local relevance geosites; 14 Regional relevance geosites; Itineraries: 15 St. Francesco trail; 16 Uguccione trail; 17 Springs trail; 18 Alta Via dei Parchi trail; 19 Dante trail; 20 WWII trails; 21 Gothic Line of Badia Tedalda position; 22 Hydrographic network

formations (San Marino and Monte Fumaiolo formations) overlying a relatively impermeable bedrock (Ligurian Units). Part of the trail retraces St. Francesco's trail, and the points of interest that can be observed during the trek are the following (starting point from Balze village, clockwise): *Balze* (G7), *Buca del Diavolo di Verghereto* (G6), *Laghi* (G5), *Tiber falls* (G4), *Tiber springs* (S1), *Sassoni* (G3), *Intra-mountain structural basin* (G1), *La Cella* (R2), *Surface karst evidences* (G8), *Senatello spring* (S2).

- The trail named *Alta* Via *dei Parchi* (also known as AVP, n. 18) runs along the Apennine ridge between Emilia-Romagna, Toscana and Marche regions. It crosses two national Parks, five regional and one interregional Park. The path is about 500 km long, and it is divided into 27 stages, two of which cross the study area (25th and 26th stage).
- *Dante trail* (n. 19) has been traced in a possible location that could link the Faggiola castle site to Colorìo and Pratieghi, and on the trail is located a panoramic view on the

Colorìo badlands (G12), the Colorìo castle ruins (H6), the Laughing stone (G13), Mt. Castagnolo military post (WW2), the Marecchia springs (S4) and Dante highER (S5) and lower spring (S6, Fig. 6).

– The *WWII trails* (n. 20) enable visitors to touch historical points of interest related to the World War II Gothic Line (also known as Pisa-Rimini line), a German defensive line of the Italian Campaign that passed in the southernmost portion of the study area. These particular trails can be enriched moving towards a Geo-historical Route inside the Historical Park of the Gothic Line of Badia Tedalda, enhancing both historical and geomorphological characteristics that led to the specific location of the Points of Interest.

Discussion and Conclusions

This research aims to enhance the geological and geomorphological heritage through actions, such as census of existing geosites; quantitative assessment of their scientific and additional values through an internationally recognised method (Reynard et al. 2016) and production of material related to the geological heritage.

These actions are to be understood as a base of helpful information to activate value processes at the territory level, which allow the improvement of geotouristic enhancement.

The authors propose to act first of all by raising the awareness of local authorities and associations active in the area regarding geological issues, aiming to include the itineraries of this research in a tourist offer for a non-expert public. In the same way, training sessions focused not only on the scientific but also on the additional values of the geosites could be organised for Environmental Hiking Guides who already carry out their activities in the study area.

The Geoheritage map could inspire the planning of thematic hikes, or the production of information brochures, to be proposed in the Pro Loco or Informative Points of the area and to accommodation and hospitality agencies on a broader scale.

In our opinion, an interdisciplinary approach should be implemented when planning cultural events, relating them to the outstanding landscape in which they take place. Operators who work in this area could also be trained in geology, geomorphology and landscape evolution through time to enhance the geological components of the territory properly. A Geotourism Information Point could be established to serve as a reference point for geotourists. It could also be planned as a digital service. In conclusion, Valmarecchia offers a complex geological and geodynamical context, where geotourism could be key to enhancing the valley. Balze village and Mt. Fumaiolo could be a test-area for a new fruition model based on mutual influences amongst natural and anthropic processes. To do this, we propose trails that cross the geological and the additional values that can improve viewers' experience, engaging them in multiple ways.

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Declarations

Conflict of Interest The authors declare no competing interests.

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