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RESEARCHING GEOMORPHOLOGICAL HERITAGE OF THE MARECCHIA RIVER VALLEY

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Out there on the rocks,

I feel exceedingly happy.

\- Naomi Uemura, Japanese solo adventurer

Abstract

Knowledge about geosites in the Marecchia River valley and Montefeltro historical region (among Emilia-Romagna, Marche, and Toscana regions and the Republic of San Marino, Northern Italy) has been put into the context of a qualitative and quantitative analysis of the geomorphological features in the study area, under the concept of Geomorphological Heritage, aiming to promote the landscape values of this region through its geomorphosites.

Along with researching the most distinctive geological and geomorphological aspects of the Marecchia valley, time has been devoted to studying different approaches and ways of transmitting the values of geological and geomorphological heritage. In fact, Valmarecchia and Montefeltro territories can be seen as an emblematic expression of a dynamic landscape that constantly changes through time and consequentially to human activities, and geosites scattered throughout the study area represent different activity levels and periods.

The basic knowledge and the approach elaborated in the framework of this thesis aims to get the public closer to geological, geomorphological and geoheritage concepts and may be helpful in the formulation of tourism promotion strategies based on geological heritage. The geomorphological knowledge has become the foundation for an integrated geotourism offer at the basin level and can be used to implement services in these territories. The experimentation of innovative methodologies has enabled to reach a broad public, enhancing the geological and geomorphological heritage without any distinction based on social origin and age.

INTRODUCTION

The theme of geological heritage transmission can, and should, be fascinating for geoscientists. Also, people working as hiking guides that focus on the connections between natural environments and geology can experience the evocative power of the language of Earth sciences, as the opportunity to accompany hikers to the presence of geosites can result in finding them astonished, intrigued, amazed, enraptured in front of millions of years of evolution, which stand still, silent, in front of their eyes. Direct experience of the geological heritage can be a tool to imprint landscapes, stories, and therefore the geological content we convey as geoscientists. To offer a set of valuable experiences in the study area, it would be necessary to unify the existing knowledge about geosites in the Marecchia River valley and Montefeltro historical region (among Emilia-Romagna, Marche, and Toscana regions and the Republic of San Marino), also by putting them into the context of a qualitative and quantitative analysis of the geomorphological features in the study area.

This investigation has been carried out under the critical concept of Geomorphological Heritage (sensu Coratza & Hobléa, 2018). It aims to promote the landscape values of this region through its geomorphosites, a goal that has also been sought thanks to the valuable collaboration with CNR - ISPC (Institute of Heritage Sciences), as it is an interdisciplinary institute whose mission is to pursue scientific excellence by encouraging innovation in the understanding, conservation and enhancement of Cultural Heritage through collaborative research involving the humanities, experimental sciences and technological applications. Working side-by-side with it meant better understanding the relationships between the geosites or geomorphosites and the cultural elements on the territory, especially during the field survey and discussion phases.

Along with researching the most distinctive geological and geomorphological aspects of the Marecchia valley, time has been devoted to studying different approaches and ways of transmitting the values of geological and geomorphological heritage. Living experiences that involve emotionally can lead to better transmission of contents and their permanence in our memory (Tyng et al., 2017), and geological contents are no exception. In Italy, geodiversity manifests itself in many surface expressions, which often embody a scenic dimension that is considerable and worthy of exaltation, especially in environmental education, considered in all its meanings, including tourism.

Valmarecchia and Montefeltro territories can be seen as an emblematic expression of a dynamic landscape that constantly changes through time and consequentially to human activities. Geosites scattered throughout the study area represent different activity levels and periods. Some of the sites are related to anthropic activities and have witnessed the human population for decades, centuries, sometimes millennia. The continuous man-land interaction manifests as a wide assortment of spectacular pieces of landscape that tell stories about destructive landslides, floods, unfortunate climate changes, mining industries, and human exploitation of natural resources. Some geosites are located in natural or semi-natural contexts, while others reside in urban environments. In some cases, the interrelations between natural landforms and urbanisation can be complex and result in landforms' partial or total invisibility. This study hopes to set the geomorphological interpretative basis for the promotion of Valmarecchia and Montefeltro geoheritage, also in terms of geotourism, as an example of Geomorphological Landscape (i.e., a landscape made up of a composition of evidence and landforms strictly interlinked by a network of genetic and functional relationships, according to Reynard & Panizza, 2005), also focusing on existing and newly proposed geosites as the best places for the transmission and dissemination of geological content, possibly through first-hand experience, i.e., guided excursions that aim to involve the user not only from a notional point of view but also from an emotional one, to convey the chosen content better.

Three geosites and one proposed geosite have been selected to carry out an educational geotouristic project named *Paesaggeo*, which aims to engage a broad public sensitive to the themes of geology and natural environments using digital tools and propose geologically themed treks to the selected geosites. Four different ways of fruition have been drafted and tested for each geosite, experimenting with different approaches to transmit the same content.

The basic knowledge and the approach elaborated in the framework of this thesis aims to get the public closer to geological, geomorphological and geoheritage concepts and may be helpful in the formulation of tourism promotion strategies based on geological heritage, with the following desirable results: lead both locals and tourists to a greater understanding of natural phenomena and their occurring times; spread knowledge about dynamic landscapes and natural, geological and hydrological risks to a broad public; promote an integrated form of slow tourism, that enhances the relationship between natural processes and populations through time.

Chapter 1.

Research objectives

To accurately describe and enhance the geosites already established and to evaluate new geosites that could be proposed in the future, an approach was chosen that would, first of all, require more excellent knowledge of the geomorphology of the area under examination, which has already been discussed (Zaghini M., 1991) but never examined in depth at the scale of the entire Marecchia River valley. For this reason, a comprehensive geomorphological survey of the study area has been planned and compiled, investigating, in particular, the relationship between human impact and the geomorphological evolution of the valley.

Knowledge of geomorphological processes and an understanding of the various multi-temporal morpho-evolutionary phases of the Marecchia river basin provides the indispensable basis for illustrating and enabling the geo-tourist to understand the significance of the individual landscape forms and how they have been shaped in the short and long term. To this end, the quantitative geomorphic analysis carried out on five sub-basins (the highest portion of the Marecchia River; Senatello River; Presale River; Mazzocco River; San Marino creek) of the Marecchia and the mapping of ancient erosion surfaces was constructive. This analysis made it possible to define the short-term erosion rate and verify the different stages of deepening of the valley in the Pleistocene up to the present situation. Therefore, the geomorphological map of the Marecchia River valley (Annex n. 1) should be considered the first of the objectives of this research.

With the tool of the geomorphological map, a geotouristic proposal has been elaborated and proposed to the Interregional Park of Sasso Simone and Simoncello, which has been identified as a primary stakeholder in promoting environmental values and good practices in the study area.

The geomorphological map was then made suitable for online publication. In fact, the geomorphological information was traduced to compile a Geoheritage online Atlas of Valmarecchia and Montefeltro, which collects these territories' geomorphological and cultural aspects related to Geoheritage. A Google My Maps project was created to share this information with inhabitants, local communities, administrations and authorities, and touristic facilities. Until now, the project has maintained a private and experimental dimension, but it is planned to be promoted and proposed in 2022.

1.1 Geomorphological map of the Marecchia River valley

The thesis is accompanied by a geomorphological map, unedited for the Marecchia River Valley area, and a simplified geological map, both at a scale of 1:50,000. The purpose of compiling the geomorphological map is to create cartography, unedited before, meant to describe the physical landscape, its processes and dynamics of transformation, as an essential basis to be able to transmit knowledge to non-experts, guiding them in the observation of geomorphological objects and giving them tools to understand their meaning, that could also be useful for all phases of territorial planning such as the Piano Paesistico Regionale (i.e., Regional Landscape Plan) or the various municipal and provincial structural plans.

The geomorphological map (Figure 1; Annex 2 of this thesis) has been compiled after examining all existing features from the Emilia-Romagna, Marche and Toscana regions and the Republic of San Marino, compared to what can be observed in the field. The geomorphological database was obtained by photointerpretation of aerial and satellite images and conducting targeted field surveys. The database consists of all the elements with geomorphological significance, i.e. the *landforms*, both natural and anthropic, which make up the morphology of the territory.

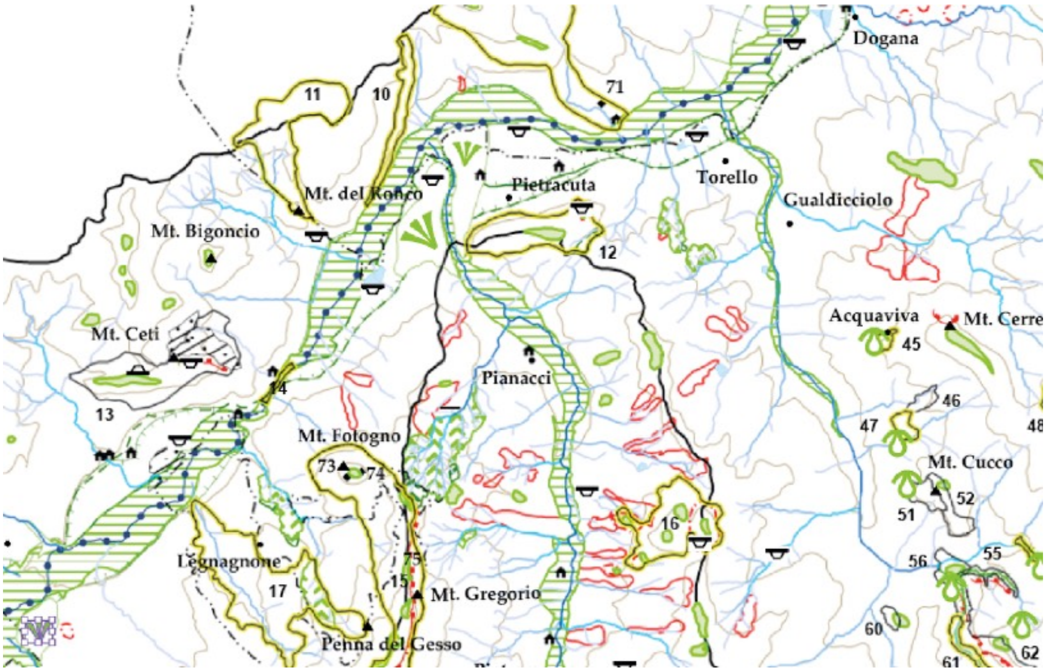

Figure 1. Geomorphological map of the Marecchia River valley (Annex 1); a detail.

1.2 GEOHERITAGE ONLINE ATLAS OF VALMARECCHIA AND MONTEFELTRO

An essential aspect of this research is the attention paid to the possibility of disseminating the results at various levels. To make the main features of the geomorphological map public and accessible to as many people as possible, it was decided to use a free tool, available by most people as it is supported by a platform now widely spread in the private and working life of each of us: Google. In fact, through the Google My Maps tool (Figure 2), it is possible to compose easily readable and shareable maps, with high accuracy of the georeferenced data provided by the possibility of uploading *.kml* (i.e., Keyhole Markup Language) files directly exported from the GIS platform. Several studies in recent years have recognised the potential of this tool and have investigated its applications in cartography and cultural or participative mapping (Flores & Gallardo, 2021; Carbone et al., 2018; Teslenok et al., 2021; Sholihah & Widodo, 2018). This specific platform also allows the user's geolocation – on mobile devices – thus permitting an accurate and precise "live"

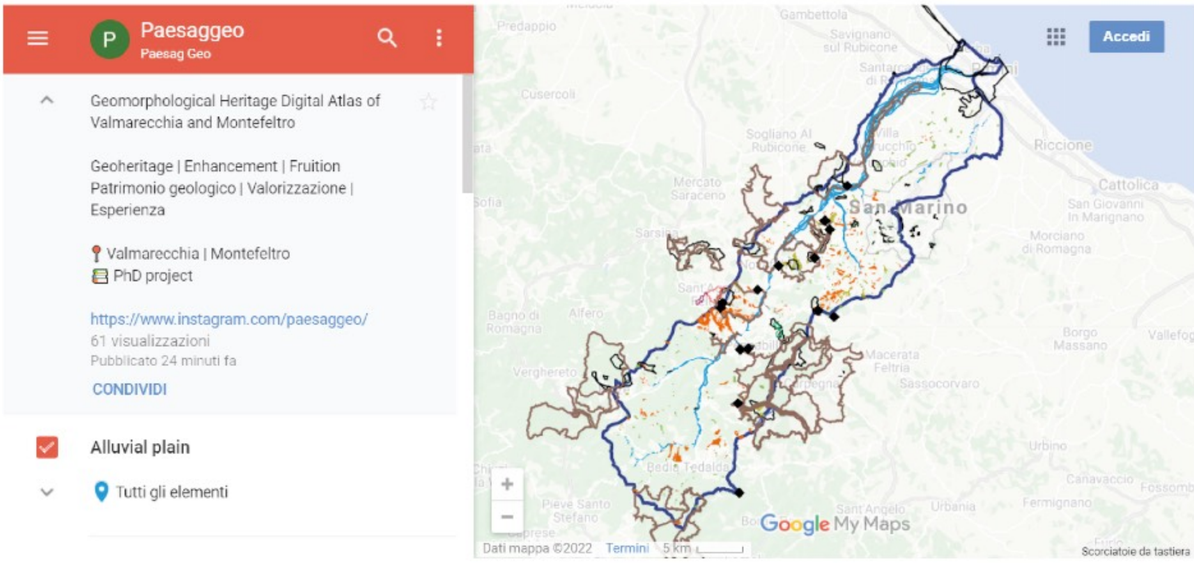

Figure 2. Geoheritage online atlas of Valmarecchia and Montefeltro, on Google My Maps workspace.

fruition of the various heritages. This aspect could be helpful in future actions of valorisation through geotourism projects.

1.3 GEOTOURISM PROPOSAL

Essential in this research would be the popularisation and promotion of a landscape geotourism project that would enhance Valmarecchia and Montefeltro as a Geomorphological Landscape and get the public closer to the specificities of each geomorphosite, highlighting, in particular, their aesthetic dimension, dynamic dimension and imbrication of scales (i.e., the particularities that make them a unique type of geoheritage, according to Reynard et al., 2009). This project has been active since April 1 2021, under the name of *Paesaggeo*, the contraction of the Italian words *paesaggio* and *geologico* (i.e., geological landscape). Different ways of promotion, communication and marketing have been tested, with the help of new media and technologies, to promote the geomorphological heritage and geomorphosites of Valmarecchia and Montefeltro as a territorial and heritage resource for sustainable development through geotourism (guided treks on specific itineraries, integrated with practices from lifelong learning, outdoor education, learn by doing), also developing an interdisciplinary method and approach to the subject.

The project has found in the Interregional Park of Sasso Simone and Simoncello fundamental support to bring 16 appointments dedicated to geoheritage inside its hiking calendar. The experiences have been distributed at four weekends during the summer 2021, one per month, promoting four types of hikes for each geosite.

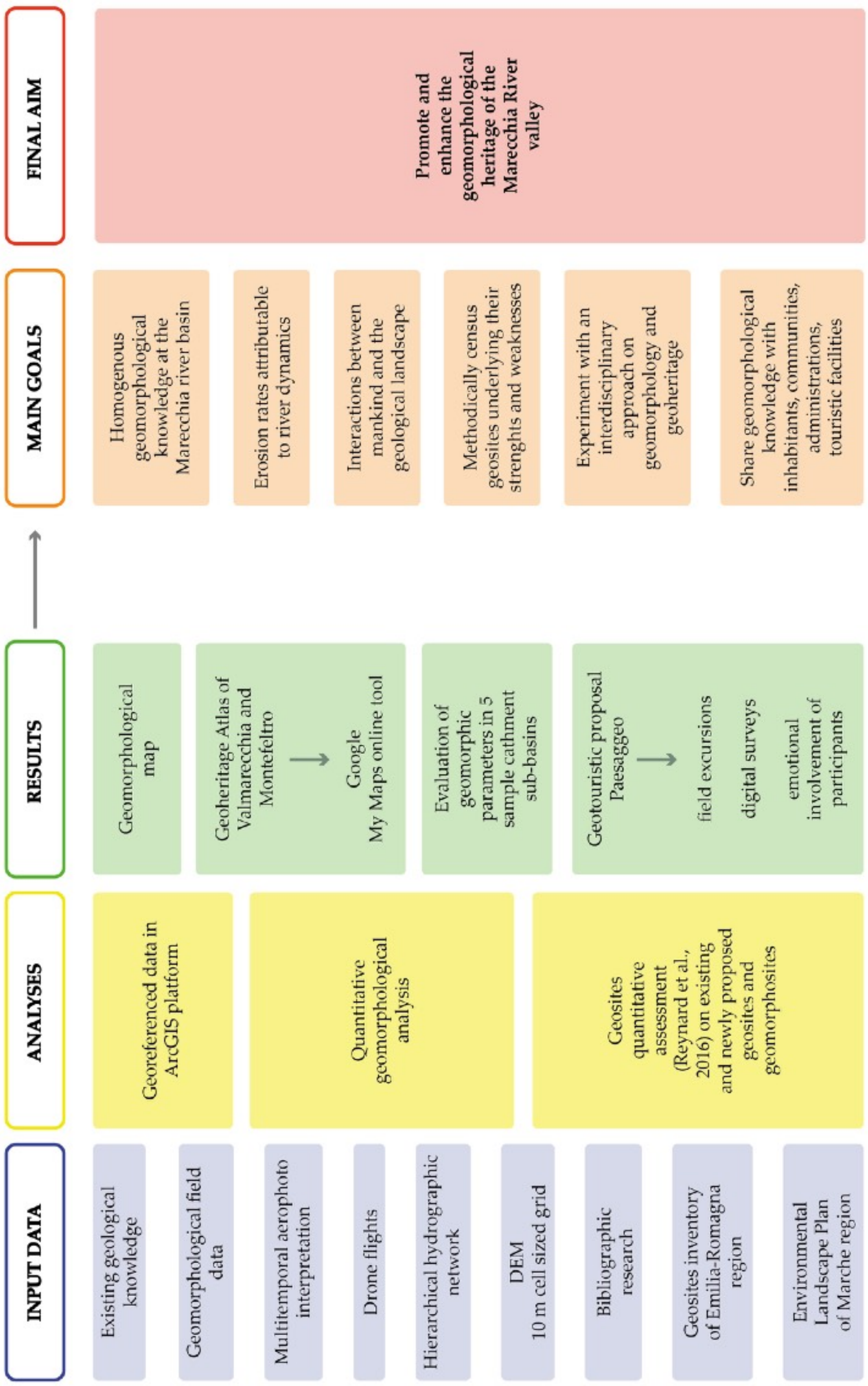

Figure 3. Methodological flowchart of the research.

Chapter 2.

Materials and methods

After bibliographical research focused both on geological and geomorphological previous works on the study area and cultural and historical values of the various sites, all existing geosites have been qualitatively described, focusing on their geomorphological values; new geomorphosites, geologically themed treks, and places of interest have been proposed to enhance the peculiarities of the study area, and all the geosites have been quantitively assessed with their scientific and additional values according to the methodology presented by Reynard et al., 2016.

Features of existing and proposed geosites and geomorphosites have been digitally mapped and described after geomorphological fieldwork. Aerial pictures, cadastres and maps have been examined, as well as historical, literary, iconographic, or archive sources, to enhance a particular event or process for each geomorphosite. Recent and ancient variations in landforms have been investigated, considering the main control factors in their development.

Contents of the following protocols and strategies have been generally taken into account while researching these topics:

- SNAI Inland Areas National Strategy (Italy, 2018);
- PST Strategic Plan for Tourism (2017) of Italian MiBACT (former Ministry of Cultural Heritage and Activities and Tourism);
- Carta su Musei e paesaggi culturali 2.0 (2016) of ICOM Italia;
- Italian Codice dei Beni Culturali del Paesaggio (Landscape Cultural Heritage Code, 2002);
- European Landscape Convention (2000);
- European Charter for Sustainable Tourism in Protected Areas (1991).

2.1 Geomorphological mapping

The first step to plan the geomorphological surveys and then compile a geomorphological map has been the realisation of a geological map of the Marecchia River valley. To do so, all available data for the area under examination have been researched, both as free web resources or requests to the Public Administrations of competence.

The simplified geological map, at a 1:50,000 scale, results come from Emilia-Romagna, Toscana, and Marche regions and San Marino territory geodata, made homogeneous in symbology and abbreviations, then revised via punctual field observations, especially along the regional or state boundaries. For this purpose, the collaboration with Emilia-Romagna Region has been of essential help, as well as the abundance of data available for free online by Emilia-Romagna[1], Marche[2] and Toscana[3] regions through the dedicated *geoportals*. Finally, professional geologists have been consulted for the Republic of San Marino territory.

The resulting geological map should not be considered accurate at a different scale. Its purpose would be to illustrate a comprehensive portrait of a complex geological setting that has been investigated by rich literature (Bonarelli G., 1929; Capozzi et al., 1991; Cerrina Feroni et al., 1997; Cerrina Feroni et al., 2002; Conti et al., 1987; Ricci Lucchi F., 1986a; Selli R., 1954; Vai & Castellarin, 1992; Zattin et al., 2002; Carmignani et al., 2004; Conti S., 1989; Cornamusini et al., 2017; Carmignani et al., 2013; Cornamusini et al., 2012). In the context of this research, the geological map should be considered a starting point for understanding how geology has affected geomorphological features and values of the valley, better represented in the geomorphological map.

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1 Emilia-Romagna Geoportal https://mappe.regione.emilia-romagna.it/

2 Marche open data https://www.regione.marche.it/Regione-Utile/Paesaggio-Territorio-Urbanistica-Genio-Civile/Cartografia-e-informazioni-territoriali/OpenData

3 Toscana Geoportal http://www502.regione.toscana.it/geoscopio/cartoteca.html#

Recently, geoheritage research has focused on mapping (Regolini-Bissig 2010; Fuertes-Gutiérrez & Fernández-Martínez, 2012; Comănescu et al., 2013; Comănescu et al., 2017; Zwoliński et al., 2018; Bouzekraoui et al., 2018) with a particular reference to geomorphological mapping, which can represent a fundamental tool in interpreting the values of the geological landscape, relating them to human development through time, and delivering a comprehensive view of the landscape evolution and interactions of its components (Knight et al., 2011; Verstappen, 2011; Otto and Smith, 2013).

The latest ISPRA criteria for geomorphological mapping (Campobasso et al., 2018) have been the primary reference for the compilation of the geomorphological map. ISPRA'S work defines geomorphological maps as the principal tools for studying and representing the earth's surface and the natural and anthropogenic processes that continuously shape it, providing an accurate representation of the forms of relief based on data collected from investigations on the ground or in laboratory analyses.

The geomorphological map represents, in fact, the forms of the earth's relief, depicting their morphographic characteristics and interpreting their origin as a function of geomorphic processes, past and present, which generated them, and identifies the chronological sequence, with a distinction between active and relict landforms. A geomorphological map should be intended to provide a complete picture of the geomorphological characteristics of the territory studied to offer the basis for predicting future evolution.

Different databases of landforms and geomorphological features are available as online resources of the Emilia-Romagna[4], Marche[5] and Toscana[6] regions; these data have been inserted into the GIS platform and then verified on the field. The resulting

[4] Emilia-Romagna geomorphological datasets https://dati.emilia-romagna.it/dataset?tags=geomorfologia

[5] Marche geomorphological features https://www.regione.marche.it/Regione-Utile/Paesaggio-Territorio-Urbanistica-Genio-Civile/Cartografia-regionale/Repertorio/Emergenze-geologiche-geomorfologiche-10000

[6] Toscana geomorphological features http://www502.regione.toscana.it/geoscopio/geomorfologia.html

map contains shapes that derive from the regional resources and newly interpreted ones. Landforms perimeters were mapped using a photo-interpretation approach at scales varying from 1:5,000 to 1:10,000 and after field verifications.

2.1.1 Field survey criteria

The field surveys were carried out throughout the whole Valmarecchia to determine geomorphological features with particular attention in the border areas that have been interpreted differently by the regional competence bodies.

The methodology adopted is classical for geomorphological maps and was based on observing and mapping landforms on the field with the help of the geolocation tool on mobile.

The geomorphological survey was particularly challenging in the Rimini town area due to the almost complete urbanisation and consequent destruction or obliteration of landforms. In this particular case, LiDAR surveys have been of fundamental importance in defining the boundaries of important geomorphological features hidden under urbanisation, such as the abandoned northern riverbed of the Marecchia River, testified by several historical sources but never detailed with such accuracy.

2.1.2 Legend: geomorphological and anthropic features

The mapped landforms include traces of paleochannels, fluvial gorges, erosion scarps, fluvial ridges, torrential fans, recent terraces, alluvial plain, active badlands and areas prone to retrogression phenomena, landslides, vertical cliffs prone to rock-falls, lateral spreading and sackung (or DGSD, i.e., deep gravitational slope deformation areas), debris cones and top erosional palaeosurfaces. These latter have been classified (S1 to S5) in the two sub-basins of the Mazzocco and Senatello Rivers, as they have been considered representative of the middle and upper Valmarecchia, respectively. The palaeosurfaces have been mapped in the field, according to topographical criteria (i.e., the maximum average slope of 10°, perimeter cliffs mapping), after verifications of their erosive characters, and thus exclusion of depositional ones, carried out on the site.

Along with natural elements, anthropic ones have been reported in the geomorphological map, such as active or abandoned quarry sites, landfills or quarry deposits, artificial canals, geosites (existing or newly proposed), protected areas, historical watermills, which are numerous and scattered along the whole valley, and the peculiar *Vasche Rupestri della Valmarecchia* (i.e., Valmarecchia rupestrian tubs). This latter feature can be considered a unique attraction in the geological valorisation of this specific area, consisting of tanks or flat surfaces carved on isolated boulders, mountain peaks, or inside caves. They can be cut in different shapes (i.e., sits, open tubs or beds, single tubs, double tubs) and a total of 17 examples can be observed.

2.1.3 Technologies to support the field survey

Aerial pictures have been compared to past and recent available satellite images of the study area to better interpret the evolutionary aspects of the mapped features. In fact, aerial pictures of Valmarecchia are freely available via online resources, such as the IGMI GAI 1954-1955 flight[7], while others have been consulted thanks to private concessions, such as the Emilia-Romagna 1976-1978 flight. Whereof interest, the pictures have been georeferenced in the GIS environment and compared with more recent satellite images to achieve information about the evolution of landforms (Figure 4).

[7] IGM GAI 1954-1955 flight on Emilia-Romagna Moka app https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/VIGMIGAI1954_H5/index.html

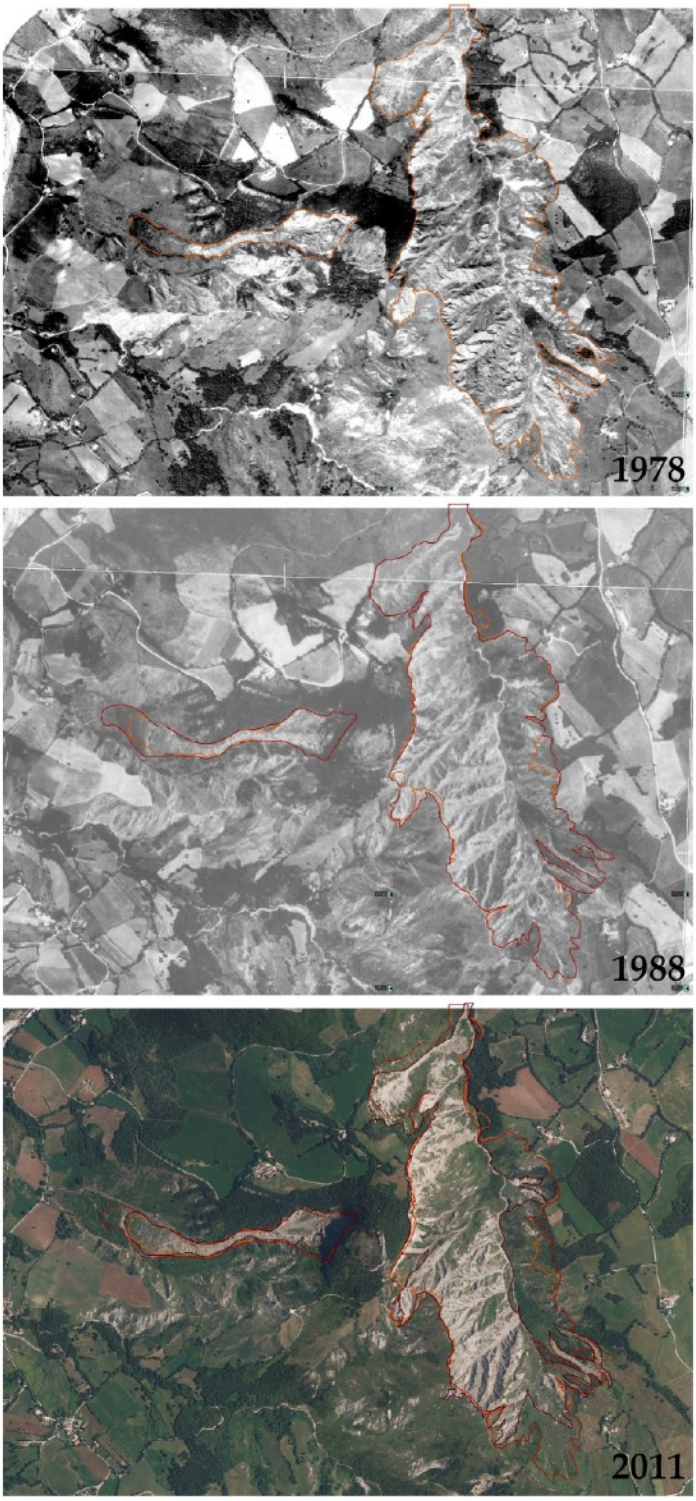

Figure 4. Comparison of aerial pictures and stellite image of Maiolo cliff and badlands.

Drone flights have been performed as another tool to understand more accurately some portions of the territory that are difficult to reach and obtain high-quality images to be used in the context of the popularisation of geosites. Several flights have been carried out on particularly significant locations, such as Maiolo (Figure 5), the Tausani ridge, Mt. Fotogno, Maciano, Scavolino, Pennabilli, Sant'Agata Feltria.

Figure 5. Drone picture of Maiolo's 1700 historical landslide area.

2.2 Geomorphological analyses

A certain level of quantitative geomorphological evaluations has been considered of fundamental importance associated with qualitative geomorphological analysis. These evaluations have been carried out following the classical geomorphological approach (Horton R.E., 1945; Strahler A.N., 1957), primarily referring to methods that enable to evaluate the short-term erosion rates, helpful in defining the landscape evolution of mountainous areas in central Italy (Ciccacci et al., 1980; Ciccacci et al., 1986; Del Monte et al., 2002; Del Monte M., 2003; Della Seta et al., 2007).

The cited works express, in particular, a noticeable spatial variability of the "denudation index" (Tu) values as the result of the mean turbid transport of streams. This is, in turn, an expression of the short-term erosion rates attributable to fluvial processes (Avena et al., 1967). This value has been determined, and other morphometric analyses have been conducted on several sample catchment sub-basins of the Marecchia River valley, aiming to define parameters - descriptive and quantitative – which express the hierarchisation of the river networks.

The Senatello (S; Figure 6) and Mazzocco River (M) basins (48.5 and 46.6 km^2, respectively) have been first selected because of their representativeness of the geological, geomorphological and geodynamic context characterising the whole Valmarecchia and expressing characteristics of the upper and middle valley.

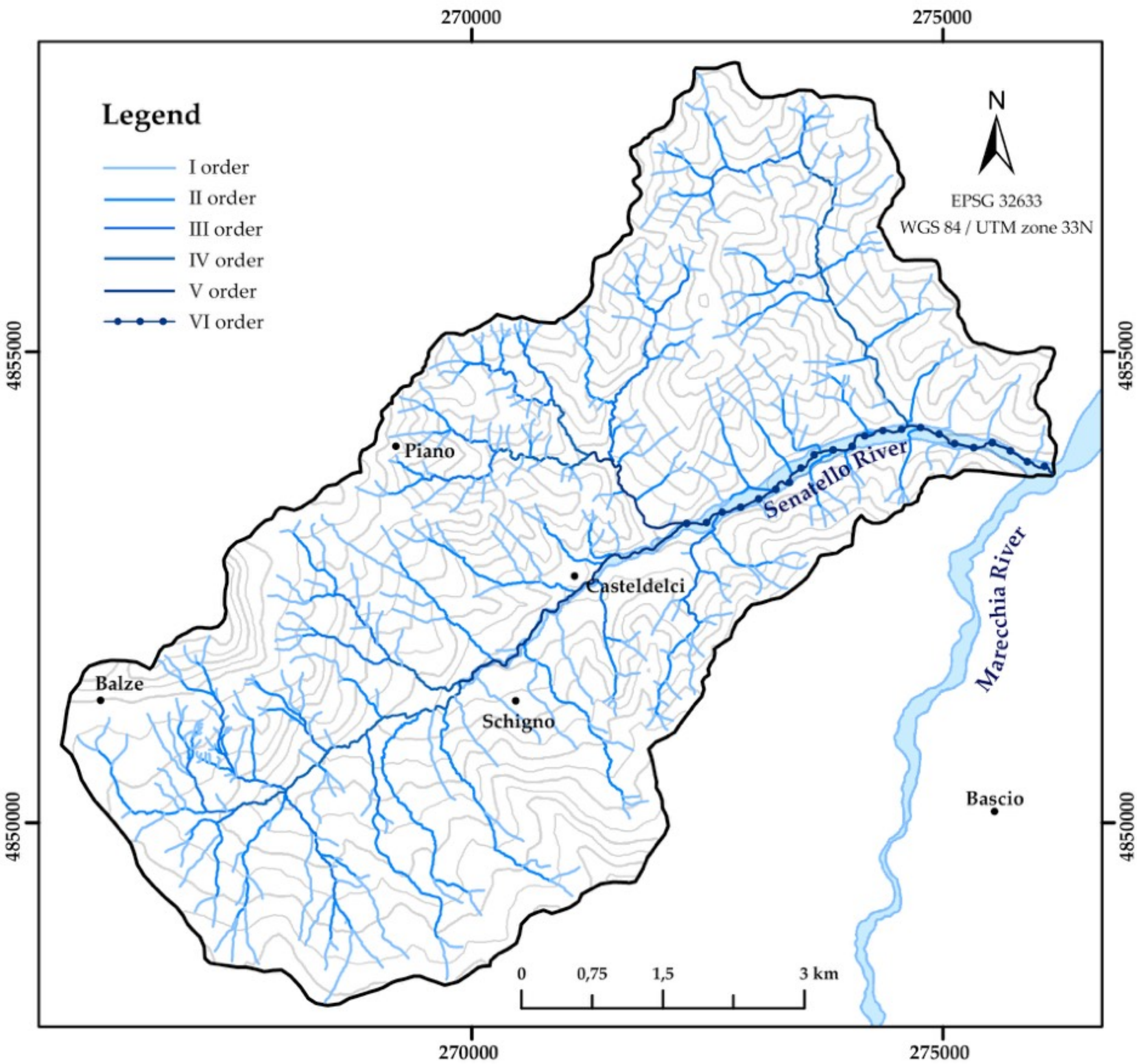

Figure 6. Senatello basin river network, hierarchised according to Strahler A.N., 1957.

Secondly, other 3 sample sub-basins have been taken into account in order to compare the first resulting values (Figure 7): the highest part of the Marecchia River (HM), the Presale River (P) and the San Marino creek (SM).

2.2.1 River network

The whole Marecchia River network has been hierarchised, according to Strahler A.N., 1957 (Figure 7), after being geo-referenced in the ArcGIS environment by comparing aerial images and the IGM Topographic Map of Italy (at a 1:25,000 scale).

The morphometric parameters obtained with the analyses are representative of the geometry and development of the drainage basins. They express the erosion, transport and sedimentation processes attributable to river dynamics (Lazzari & Schiattarella, 2008; Lazzari & Schiattarella, 2010). Such analyses have been conducted on the Senatello and Mazzocco Rivers catchment basins on the assumption that climate conditions have remained constant throughout the latter half of the Holocene (Schiattarella et al., 2004).

The geomorphic parameters which have been determined for the two sample areas are the following:

- Nu = number of river channels of u order (Horton R.E., 1945);
- Ndu = number of river channels of u order that merge into river channels of u+1 order;
- A = area of the basin (km^2);
- ∑L = total sum of river channel lengths (km);
- D = drainage density = ∑L / A (km/km^2) (Horton R.E., 1932);
- L= main channel length (km);
- Rf = shape factor = A / L2;

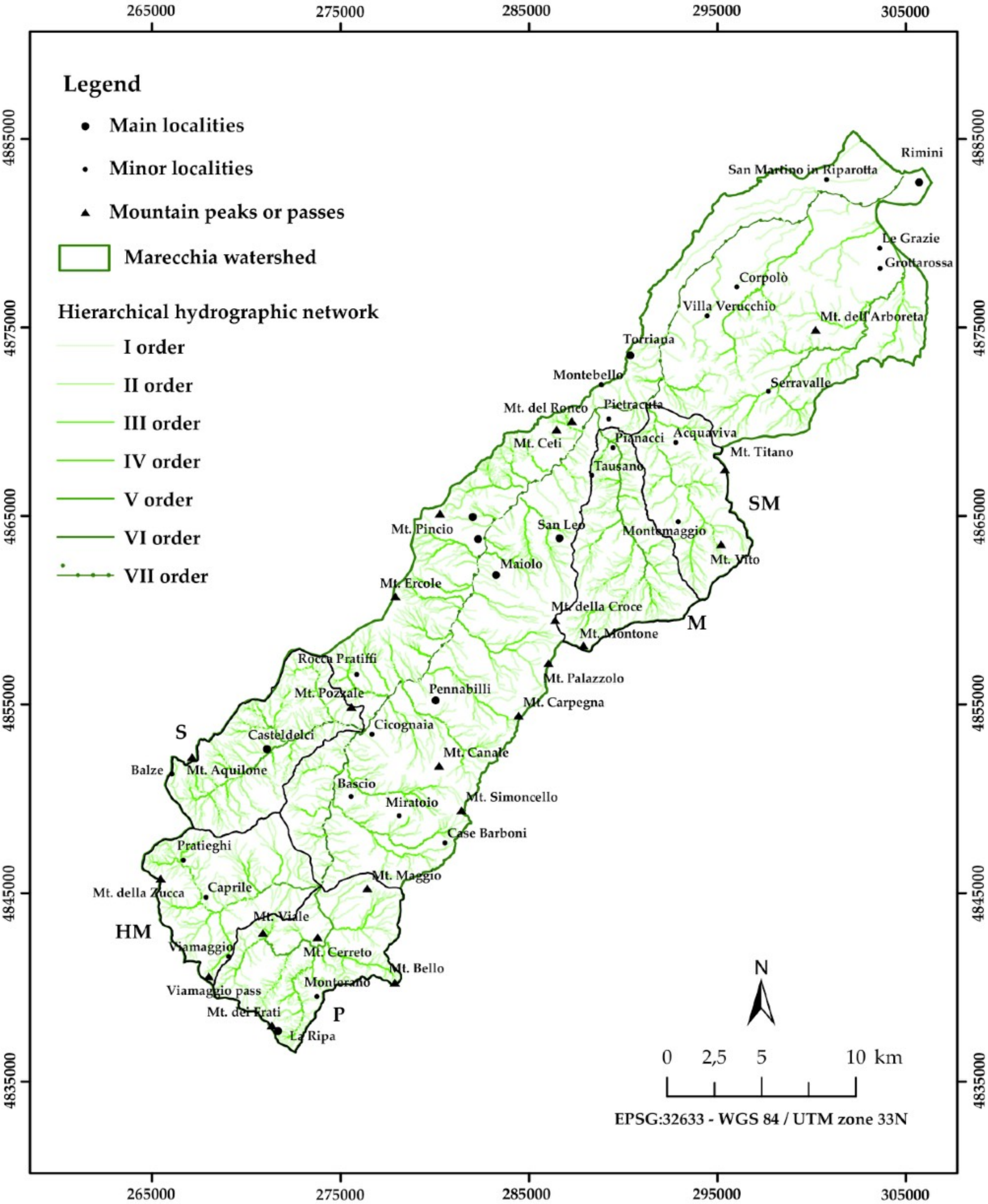

Figure 7. Marecchia basin river network, hierarchised according to Strahler A.N., 1957. Marked with a black perimeter, the river basins subject to quantitative analyses: S - Senatello River; HM - highest part of the Marecchia River; P - Presale River; M - Mazzocco River; SM - San Marino creek.

- Rc = circularity ratio = 4πA / P2 (Miller V.C., 1953);
- Ru = uniformity index or compactness coefficient = 0,2841 * P / A0,5 (Gravelius H., 1914);
- Ra = elongation ratio = 2 / Lb * (A / π)0,5 (Schumm S.A., 1956);
- S = sinuosity index = D / (Nu / A);
- P = perimeter of the basin (km);
- F1 = first order channels frequency = N1 / A;
- Rb = bifurcation ratio =Nu / Nu+1;
- Rbd = direct bifurcation ratio = Ndu / Nu+1;
- R = bifurcation index, R = Rb - Rbd;
- Ga = hierarchical anomaly number, the smallest number of first order streams necessary to make the drainage net perfectly conservative (Melton M.A., 1957); Ga = $\sum_{s-2}^{i=1} \sum_{s}^{r=i+2} N_{i,r} * f_{i,r}$;
- Δa = hierarchical anomaly index = Ga / N1;
- ga = hierarchical anomaly density = Ga / A.

Estimating the drainage network extension and organisation degree led to the evaluation of denudation power within the drainage basins. To this end, some relations were used which allow calculating the denudation rate index, expressed by the suspended sediment yield (Tu, t/km^2/yr) that was computed as a function of the morphometric parameters determined by Ciccacci et al., 1980 using the following equation:

- log Tu = 1,82818 log D + 0,01769 ga + 1,53034

The Turbidity Unit Index (Tu) is a set of equations with high determination coefficients derived by Ciccacci et al., 1986 through statistical correlation of measured suspended sediment yield data at the outlets of 20 gauged Italian watersheds with selected geomorphic and climatic parameters. This value directly expresses the specific effect of recent or present linear erosion processes inside the drainage basin and give information about the erodibility of outcropping rocks. Tu index is also independent from the catchment area, as it can be used to compare different drainage basins (Ciccacci et al., 1979).

The Tu value has been then converted in denudation height or erosion rate (Ta, expressed in mm/yr), considering the average density of outcropping rocks of sample areas according to the following expression:

- $Ta = Tu / \gamma s * 10^{-3}$ (Ciccacci et al., 1986)

where Tu is the suspended sediment yield and γs is the specific weight of the drained rocks. The value of γs, determined by the simple average of the values assigned to the single geological formations in the two sub-basins, that are comparable to each other, is equal to 2.5 gr/cm^3 (Table 1).

2.2.2 Palaeosurfaces and morpho-evolutive stages

The described analysis to determine short-term erosion rates cannot be separated from the broader geological history and evolution of this sector of the northern Apennines. The Apennines are a young and tectonically active mountain chain, having been uplifted above sea level primarily within the Pliocene (Ricci Lucchi F., 1990). 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 & Granger, 2008).

The erosive and denudation phases of the uplifted Apennine mountains have developed during ancient stationing of the local base levels of erosion. The morphogenesis of soft relief paleo-landscapes and/or erosional planation surfaces has been modelled in discordance mainly on the Eocene and Miocene terrigenous units (San Marino formation, SMN) and in the Plio-Quaternary clastic deposits.

Geological Formation	Abbr.	Lythotype	γs gr/cm^3
Acquaviva Formation	AQV	Coarse sandstones with pebbles. Subordinate are the conglomerate levels, generally lenticular.	2.4
Argille Varicolori Formation	AVR	Chaotic polychromatic clays with intercalated levels of limestone, calcilutites, fine sandstones, siltstones, black clayey marls and marls.	2.3
Marnoso-Arenacea Formation	FMA	Turbidite sandstone-pelite layers and intercalations of marly hemipelagites.	2.7
Ghioli di letto Formation	GHL	Silty-marly clays with thin layers of siltytic sandstones and, in the upper part, bituminous mudstones and carbon levels.	2.3
Monte Fumaiolo Formation	MFU	Ungraded hybrid sandstones with medium-thin stratification.	2.7
Monte Morello Formation	MLL	Alternation of limestones and marly limestones, turbidite limestones and marls.	2.7
Monte Morello Formation - Case Nuove or Marne Rosate lithofacies	MLLa	Marls and marly limestones alternating with dark and polychrome clays.	2.4
Sillano Formation	SIL	Alternation of limestones and mudstones. Locally calcareous marls are present.	2.4
San Marino Formation	SMN	Organogenic limestones and calcarenites rich in bioclasts.	2.7
San Marino Formation - base Member	SMN1	Massive biocalcarenites, calcirudites and polygenic conglomerates, sometimes with intercalations of more arenaceous layers.	2.5
San Marino Formation - stratified limestones Member	SMN2	Very thick layers of biocalcarenites.	2.4
Villa a Radda Formation	RAA	clays alternating with layers of sandstone with carbonatic cement.	2.4

Table 1. Summary table of the γs values and descriptions of the geological formations of the Mazzocco and Senatello river basins.

In the Apennines, the planation surface (PS) described by Coltorti & Pieruccini, 2000 levelled all the topographic contrasts. It represents a valuable marker for deciphering the Plio-Quaternary evolution of landscape and for allowing to discriminate between pre- and post-planation tectonic activity. Moreover, it represents a key tool for detecting neotectonics movements and assessing seismic hazard in areas where Plio-Quaternary deposits are not preserved.

In the study area, the presence of small valleys, large and flared, with riverbeds suspended and, more generally, of a sweet landscape with a weak gradient, currently represented by relict and suspended surfaces at different heights, testifies continental morphogenesis, superimposed on the previous one, and responsible for the obliteration of the older morphological evolution traces.

These surfaces have been mapped for the whole Marecchia valley, by defining them in the field and by means of a slope map calculated using the DEM of Tarquini et al., 2007. They measure from 2,000 to 100,000 m^2, with slopes not exceeding 10° and low energy of relief (Figure 8).

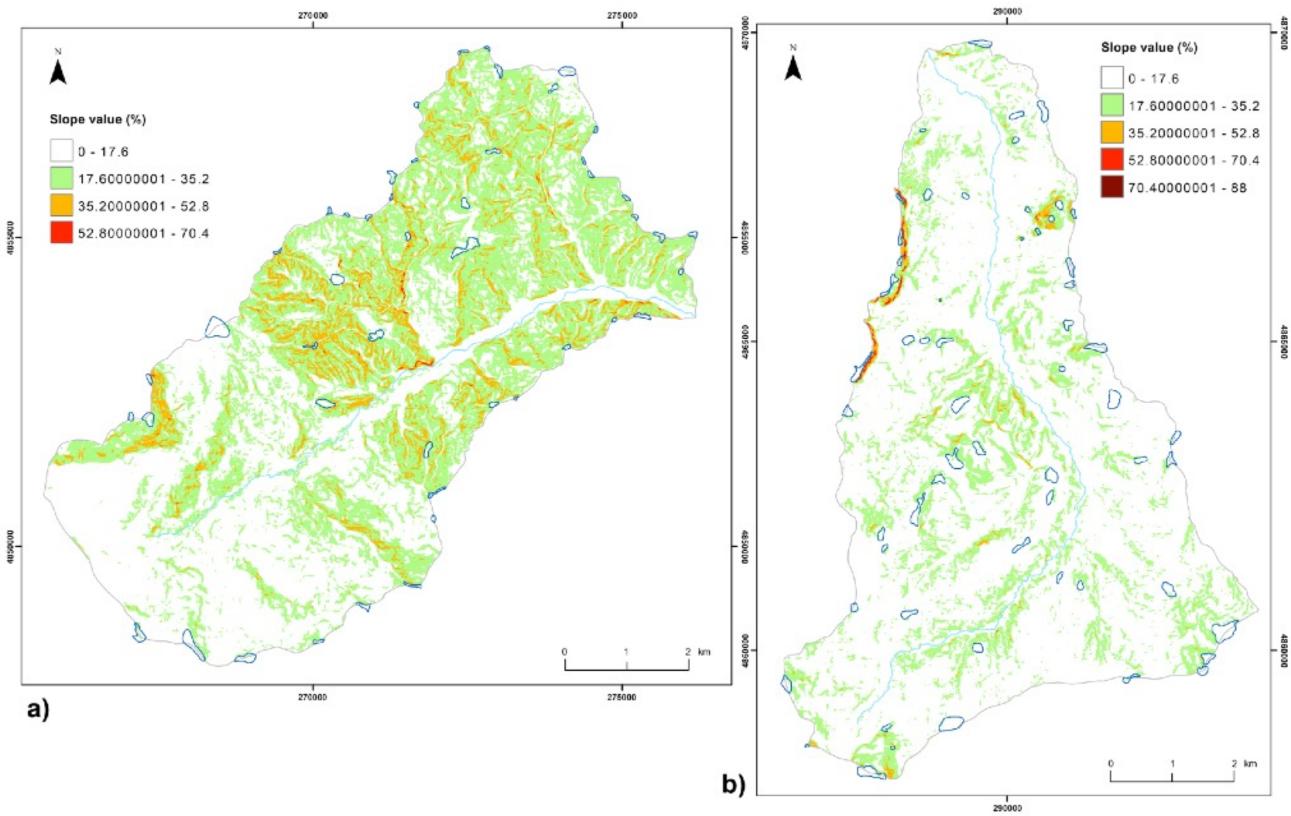

Figure 8. Erosional palaeosurfaces of the Senatello (a) and Mazzocco (b) river basins.

2.3 Geosites and geomorphosites

According to one of the most commonly accepted definitions, a geosite can be defined as a site location area or territory in which it is possible to identify a geological or geomorphological interest for conservation. Thus a geosite is a place peculiar to geology, and the set of geosites constitutes the Geological Heritage of a given territory and expresses its geodiversity.

The term geomorphosites proposed by Panizza M., 2001 is the most widely used in literature for qualifying landforms that make up geomorphological heritage. The assessment of a geomorphosite generally reveals several heritage values associated with the site. Nevertheless, geomorphosites can be considered geosites that present a broader set of values (Coratza & Hobléa, 2018).

Geomorphosites have three main characteristics that make them unique and distinctive types of geoheritage: the aesthetic dimension, the dynamic dimension, and the imbrication of scales (Reynard et al., 2007). These specificities are essential and can influence and condition choices in different contexts: educational and training activities, conservation and management, hazard and risk assessment.

In terms of activity, geomorphosites, more than other categories of geosites, can be both highly dynamic, allowing the best observations of ongoing Earth's processes, or more 'static' sites showing the evidence of past processes and events (Pelfini & Bollati, 2014; Reynard & Coratza, 2016). Although the public frequently perceives the geological heritage with a static approach and the museological view, landforms and landscapes are not fixed and unchanging but are dynamic and developing through time. At the same time, landscapes host landforms that bear the signatures of past processes operating under different climatic conditions (Coratza & Hobléa, 2018). To characterise the scientific values of geomorphosites, the geomorphologist dealing with these particular geosites should be polyvalent: they must be able to mobilise the whole spectrum of geomorphological knowledge (Coratza & Hobléa, 2018). Because geomorphosites present additional values related to aesthetics, human history, and culture, he must also be open to numerous other human and cultural geography issues. This characteristic is, for instance, at the foundation of the definition of 'cultural geomorphology' (sensu Panizza & Piacente, 2003, 2009, 2014; Reynard & Giusti, 2018). According to the territorial context, the geomorphologist can also be involved in the management of the geomorphological heritage. The geomorphologist working on geoheritage should also master the knowledge transfer protocols and the mediation know-how. These issues build the basement of a new branch of geomorphology that authors called "Heritage Geomorphology" (Coratza & Hobléa, 2018) and includes cultural geomorphology. The concepts of Cultural and Heritage Geomorphology have been considered the motivation and direction to carry out the present research.

Geological heritage assessment has been largely discussed in the scientific literature of the last decades, and several qualitative and quantitative methodologies for assessing geomorphosites has been proposed (Reynard et al., 2016; Mucivuna et al., 2019). The geosites inventory was based on the existing ones, established by Emilia-Romagna and formally instituted at a regional scale with the Regional Law No 9/2006. Several of the municipalities where the geosites are located (Talamello, San Leo, Maiolo, Novafeltria, Sant'Agata Feltria, Pennabilli and Casteldelci) were integrated into the province of Rimini (and thus in the Emilia-Romagna region) from Marche region in 2006 through a referendum, with actual accomplishment in 2009. According to the promoting committees, the reasons for this passage have to do with geographical, historical and cultural issues. In fact, for these municipalities, the reference territory from an economic, health and educational point of view has always been the province of Rimini. Also, the other two municipalities underwent the same procedure back in 2007, Sassofeltrio and Monte Copiolo, with the accomplishment of the resulting annexation to the Emilia-Romagna region just a few months ago, in May 2021.

The geosites on these specific municipalities had already been defined and spatially delimited to a comparable extent by Marche regional authorities inside the Piano Paesistico Ambientale Regionale (*Regional Environmental Landscape Plan*) as areas characterised by geological and geomorphological important features (B.U.R.M. No 120, 24/9/1990).

The Emilia-Romagna and Marche sources enhance the geomorphological component as a critical value to most geosites. The geotouristic fruition has the potential to be strictly related to geomorphological features. In addition, the study area was popularised by Regione Emilia-Romagna through a geothematic map, named "Geoenvironmental itinerary in the Marecchia Valley - discovering Valmarecchia, geodiversity and a unique geological landscape in Romagna", presented in 2015 and freely available online[8].

According to Panizza (2001) and Panizza & Piacente (2003), geomorphosites are '*landforms with particular and significant geomorphological attributions, which qualify them as a component of a territory's cultural heritage (in a broad sense)*', where value may be given by scenic, scientific, socioeconomic or cultural features. This definition appears the most suitable in a geotouristic or didactive context (Coratza & Hobléa, 2018).

Under this definition, the geological and geomorphological heritage of the area has been inventoried starting from the already catalogued geosites of the Emilia-Romagna Region, implemented with new proposals for geosites and with the assessment of the sites' value, according to Reynard et al., 2016.

The values were attributed through a score from 0 to 1, according to observations as objective as possible, but which cannot exclude a certain level of subjectivity due to the personal interpretation of different values. The resulting scores have been summed for each geosites to get a quantitative expression of their comprehensive quality.

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[8] Emilia-Romagna thematic map "Geo-environmental itinerary in the Marecchia Valley" https://ambiente.regione.emilia-romagna.it/it/geologia/geologia/geositi-paesaggio-geologico/itinerari/Itinerari-valle-Marecchia/

The protection status of the geosites has been expressed considering the existing SIC-ZSC (Sites of Community Importance and Special Areas of Conservation, as defined by the Habitats Directive, or Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora), ZPS areas (Special Protection Areas as defined by the Birds Directive, or Council Directive 2009/147/EC on the conservation of wild birds) and Natural Parks or Reserves officially registered as EUAP protected areas (i.e., the official list of protected natural areas as defined by Italian Law 394/91) that subsist on the territory (Figure 9).

2.4 Geotourism products elaboration

The geotourism proposal elaborated in this research wants to consider the scientific and additional values attributed to geosites or geomorphosites. It considers certain landscapes' impact on human perception as extremely important. It was decided to question an aspect that has been rarely considered in geosciences, namely the emotional involvement felt by a user (inhabitant or tourist) when faced with a geological landscape. In other words, how does it make us feel to be in front of a rocky cliff, a gully, a landslide, a quarry? Is it possible that people feel similar emotions when faced with similar landscapes or processes?

The interaction between geological phenomena and man generates an involvement beyond the cognitive sphere, interacting with our emotions. Faced with 'negative' phenomena, such as earthquakes and floods, perception is naturally conditioned by thoughts of possible damage or fatalities associated with it. For example, we may feel horror in front of a landslide or fear of an earthquake. This aspect has been investigated mainly in environmental education in places with a high seismic or hydrogeological risk (Piangiamore et al., 2021; Piangiamore et al., 2015; Piangiamore & Musacchio, 2017). However, the natural environment is also spontaneously a vehicle for positive feelings and emotions.

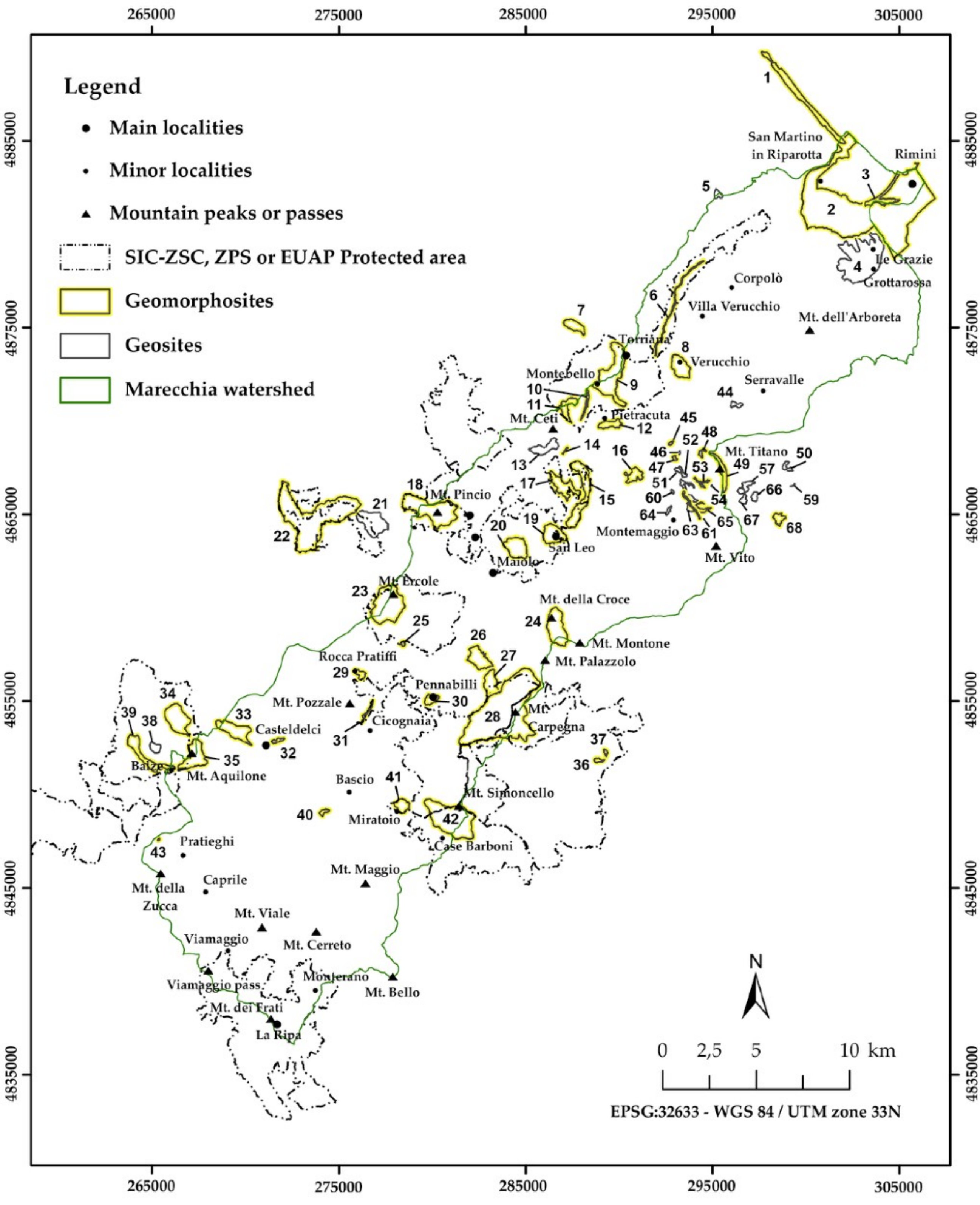

Figure 9. Geosites, geomorphosites and protected areas of Valmarecchia, Montefeltro and the Republic of San Marino.

The geological heritage plays a fundamental role in determining the characteristics of habitats and often contributes to its eventual scenic and astounding, 'impressive' character, the one that sticks in our memory. At the same time, geological heritage is the bearer of the concept of complexity, which is expressed in terms of both time and space and is the same component that more or less consciously makes us amazed when we see a geological landscape (Sibi & Valletta, 2014). It is demonstrated that the effects of viewing extraordinary and spectacular landscapes are distinctly beneficial to the observer and positively influence behaviour and psychology through an improvement in mood, emotions, and prosociality (Joye & Bolderdijk, 2015). Including the component of emotional involvement in the context of the dissemination of geological heritage could be a starting point for more effective communication. One could interest the user from different points of view, stimulating his scientific curiosity and aiming to instil in him a sense of astonishment, wonder, joy, or other. In this way, equal emphasis would be placed on the sensations felt during the experience and on the contents, which could thus be more easily memorised and preserved within the user's experience. There is significant evidence that it is easier to remember emotional events more clearly and accurately, and longer than neutral events. (Tyng et al., 2017).

Humans are deeply linked to some fundamental emotions as part of our mammalian evolution; seven primary emotional systems have been identified, which underlie the brain's functioning and determine unconditional emotional responses (Panksepp J., 1998). *Seeking* led animals to explore and find resources; *rage* (or *anger*) led to their defence. *Fear* is necessary to avoid danger, while *lust* is to identify potential partners. Later mammals developed sociality and thus new emotional systems. *Care* is needed to look after offspring. *Panic* (or *sadness*) results from separation distress and helps maintain contacts and socialites. *Play* (or *social joy*) has to do with the need for competitive experiences or games in childhood; it leads to the construction of lasting ties in social life, allowing one to experience limits and face adult life with fun.

Inspired by these principles, the project *Paesaggeo* was conceived and developed through different experiences, both as online and live actions.

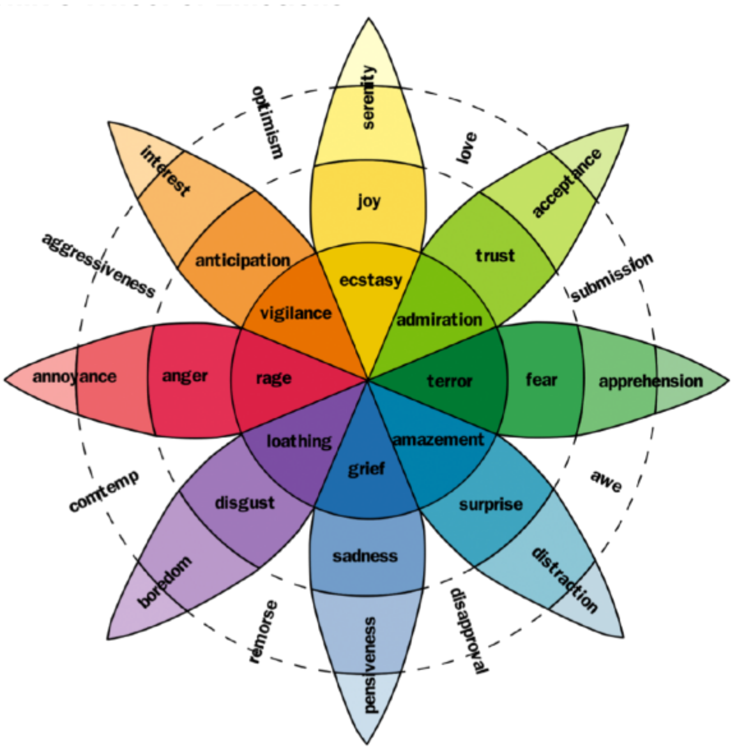

Figure 10. Robert Pluchick’s Wheel of Emotions. Source: Wikimedia Commons: https://commons.wikimedia.org/wiki/File:Plutchik-wheel.svg

2.4.1 Paesaggeo project proposal

As the first step in trying to better understand the relationship between geological landscape and emotions, an online survey about landscape perception was conceived with the help of the psychologist Isabella Ferlini, an expert in Ecopsychology, the branch that deals with nature and humanity and their mutual relationships.

The main objective of this online survey is to collect people’s perceptions of different geological landscapes, based on photographs and expressed as a multiple-choice among different emotional fields.

This survey was firstly popularised online by creating the Instagram page @paesaggeo[9]. This page intends to promote the geological landscape of Valmarecchia and Montefeltro and illustrate with a simple language the aims of the present research, putting it into context through various "blocks" of explanatory posts. The graphic design reflects the project's identity and facilitates its positioning in users' minds, thus making it recognisable.

The coordinated image and logo play with lines and colours reminiscent of landscapes and geological strata (Figure 11). The graphic look of the posts means highlighting some parts of the images through a "reverse filter" or a colour filter to the contour elements of the picture that leaves the geological components in natural colours. This is symbolic of how we put filters (emotional, cognitive, content) on natural assets, and the project aims to present the geological heritage in its authenticity (Figure 12). The Instagram page @paesaggeo was promoted through the direct invitation of possible related accounts on the social Instagram, the use of specific hashtags and geotags and, finally, the direct and indirect promotion to the accounts of personal friends and acquaintances.

The page was also used to promote live appointments by creating specific content. This platform has, in fact, a better rendering of two essential components of social media: hashtags and geolocation, which have been utilised for a greater engagement of users and the promotion of a live experience program throughout the summer.

Another critical aspect in elaborating the geotourism proposal was the desire to experiment with different modes during trekking tours, bringing people a live, first-hand experience of the geological heritage. Not all hikers are the same, and the various proposals for accompanying people in nature in the study area reflect the market's needs. Analysing the recent proposals of the environmental guides operating in the Valmarecchia and Montefeltro areas, it is clear that there are different types of users participating in experiences in nature.

[9] *Paesaggeo* Instagram profile https://www.instagram.com/paesaggeo/

Figure 11. *Paesaggeo*'s project logo.

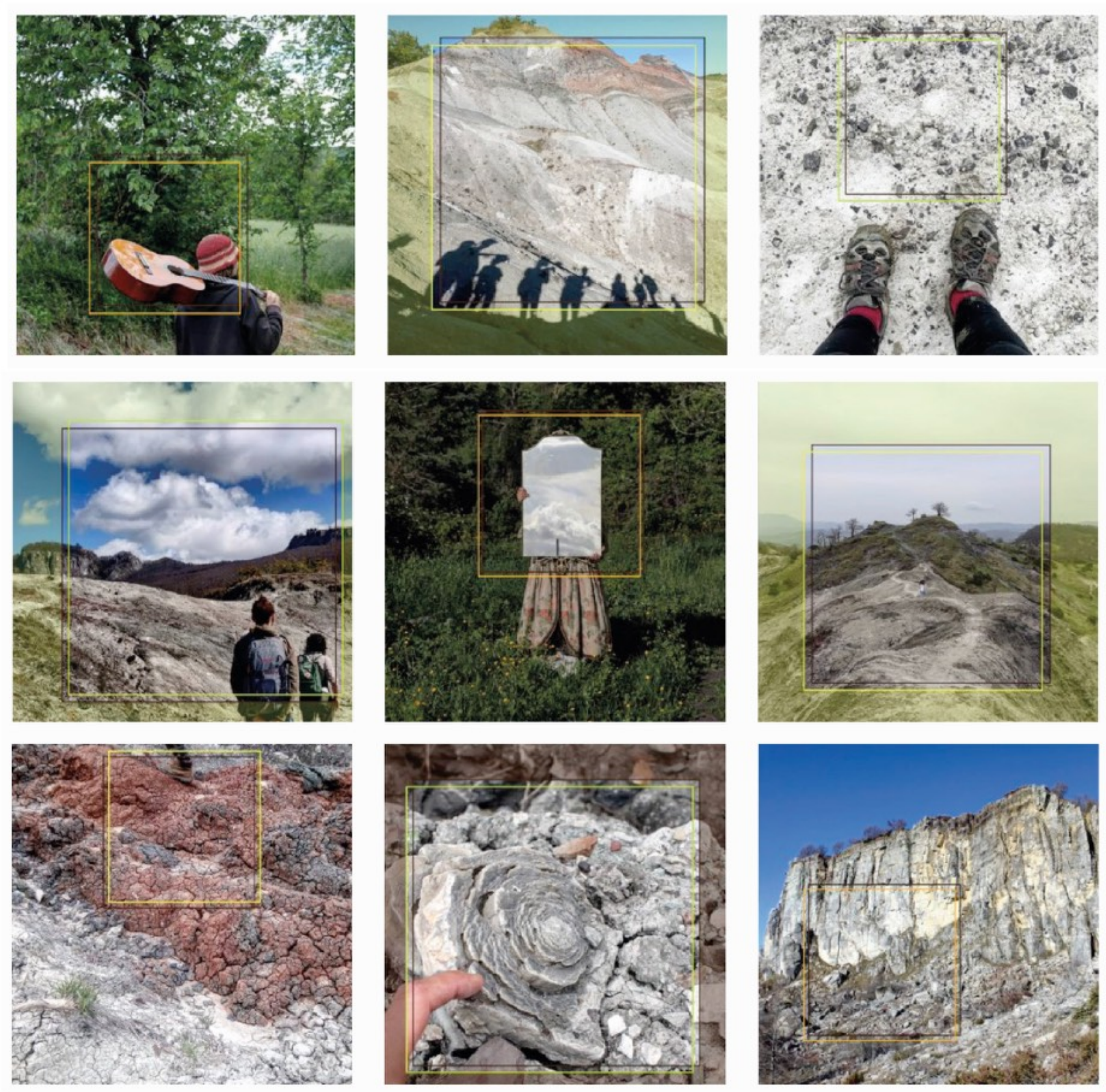

Figure 12. Some examples of *Paesaggeo*'s Instagram feed.

From slow tourism to mountain-bike cycling tourism, from theatrical narrations in the woods to snowshoeing on the ridges, from wine and food events to concerts in nature. This wide-ranging proposal interfaces with a public of adults and families with children, who differ in how they approach the guided excursion: some are looking for a relaxed experience, where they can enjoy nature in an easily accessible context. Others want to put themselves to the test and are curious about going off-trail. Others like to participate in interdisciplinary experiences in a natural setting.

A touristic proposal that uses natural landscapes in a didactic or entertaining way, based on imagination and emotion about Earth history, may provide interesting developments (Pralong J.P., 2006), especially considering that tourists and day-visitors consider crucial issues such as environment and nature, educational tourism, culture, history, events, entertainment fun (Morucci B., 2003). The so-called "emotion culture" (Origet du Cluzeau & Vicériat, 2000) have influenced visitors to be more and more prone to a type of tourism that enhances experiences and sensations (Pralong J.P., 2006). This is also evident in the evolution of the touristic offer in terms of more and more "experiential" events. (Gulotta G., 2019; Polidori L., 2015; Di Vittorio A., 2010; Prentice et al., 1998; Prebensen et al., 2018; Stamboulis & Skayannis, 2003; De Bruin & Jelinčić, 2016).

The underlying question has been which types of experiences could be most effective in transmitting geological content, and to answer it four different approaches were developed so that each experience stimulated various emotional fields. The four types of themed treks were tried out in the summer 2021 thanks to the involvement of the Sasso Simone and Simoncello Park hiking calendar, during which it was possible to propose a total of 16 experiences dedicated to the geological landscape, collected in a series of events titled:

1. *Escursione nel Paesaggeo* (i.e., Trekking in a Geological landscape) – "test" mode;

2. *Esploriamo un Paesaggeo* (i.e., Let’s explore a Geological landscape) – “exploratory” mode;
3. *Una storia nel Paesaggeo* (i.e., A story in the Geological landscape – “immersive” mode;
4. *Ascoltiamo il Paesaggeo* (i.e., Let's listen to the Geological landscape) – “artistic” mode.

At the beginning of each experience, a general context to the research was given, and at the end, all the participants were asked to answer a brief survey about what they had experienced. These additional surveys offer a direct measure of how the four different types of guided geologically themed treks can engage the public emotionally.

The communication of each event was developed on several fronts. The collaboration with Sasso Simone and Simoncello Park made it possible to have the review promoted as digital posters (Figure 13) on the official website[10], through the Facebook account[11] (followed by more than 9000 people) as Events, and as part of the content of a weekly newsletter (that counts more than 4000 subscribers), other than being popularised via monthly cumulative paper flyers distributed in the provinces of Rimini and Pesaro-Urbino.

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[10] Microcosmi page on Natural Park of Sasso Simone and Simoncello website http://www.parcosimone.it/microcosmi2021/

[11] Natural Park of Sasso Simone and Simoncello Facebook page https://www.facebook.com/ParcoSassoSimoneESimoncello

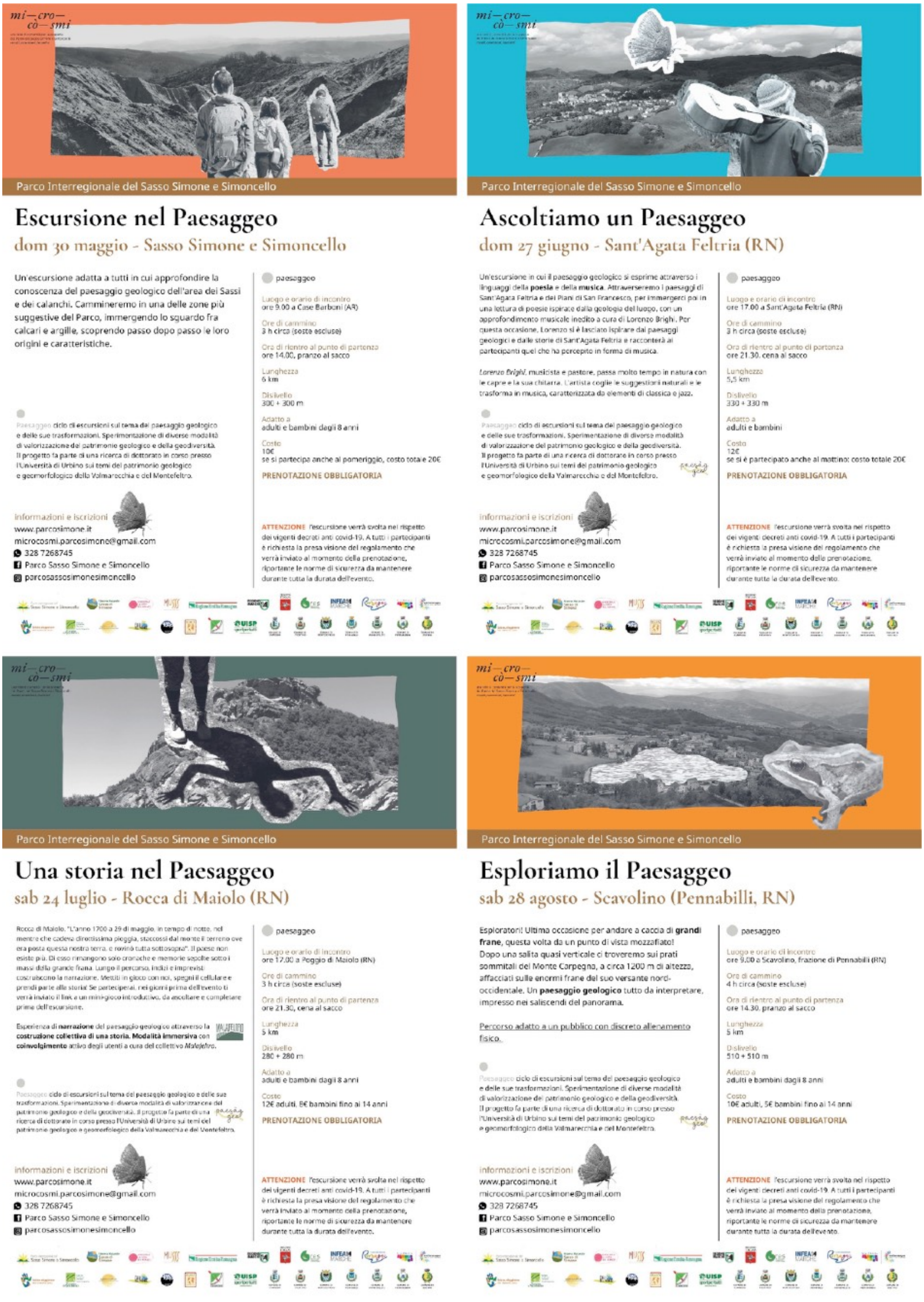

Figure 13. Some examples of *Paesaggeo*'s dedicated digital posters.

Chapter 3.
Valmarecchia and Montefeltro historical region

The study area focuses on the Marecchia River basin, from its springs in Toscana territories to Rimini; part of the Marche and Toscana regions and part of the Republic of San Marino is located in the area, thus have been objecting of study.

Population in this valley has been influenced by the existence of the Ariminensis Road, connecting Rimini to Arezzo and the Tiberina valley. Since ancient times, this has caused the growth of settlements to key sites alongside the Marecchia River. The spotted characterisation of settlements was strictly connected to geomorphological land features, and the landscape evolution played a crucial role in history in determining whether a settlement would be long lasting or not (Nesci & Sacco, 2010).

3.1 Administrative context

The Marecchia Valley stretches over two states, Italy and the Republic of San Marino, and three regions (from its source in Toscana to its mouth in Emilia-Romagna, touching on the Marche region), it crosses three municipalities in Toscana (Badia Tedalda, part of the municipality of Sestino and a very small portion of the municipality of Pieve Santo Stefano), two in Marche region (Carpegna and Monte Grimano Terme) and fourteen in Emilia-Romagna region (Rimini, Santarcangelo, Verucchio, Poggio Torriana, Talamello, Novafeltria, San Leo, Maiolo, part of the municipality of Montecopiolo, Sassofeltrio, Sant'Agata Feltria, Pennabilli, Casteldelci and a small part of the municipality of Verghereto, with the village of Balze; Figure 14).

On 2006 an advisory referendum was held on the transfer from Marche to Emilia-Romagna of seven municipalities of the Alta Valmarecchia (Casteldelci, Maiolo, Novafeltria, Pennabilli, San Leo, Sant'Agata Feltria and Talamello).

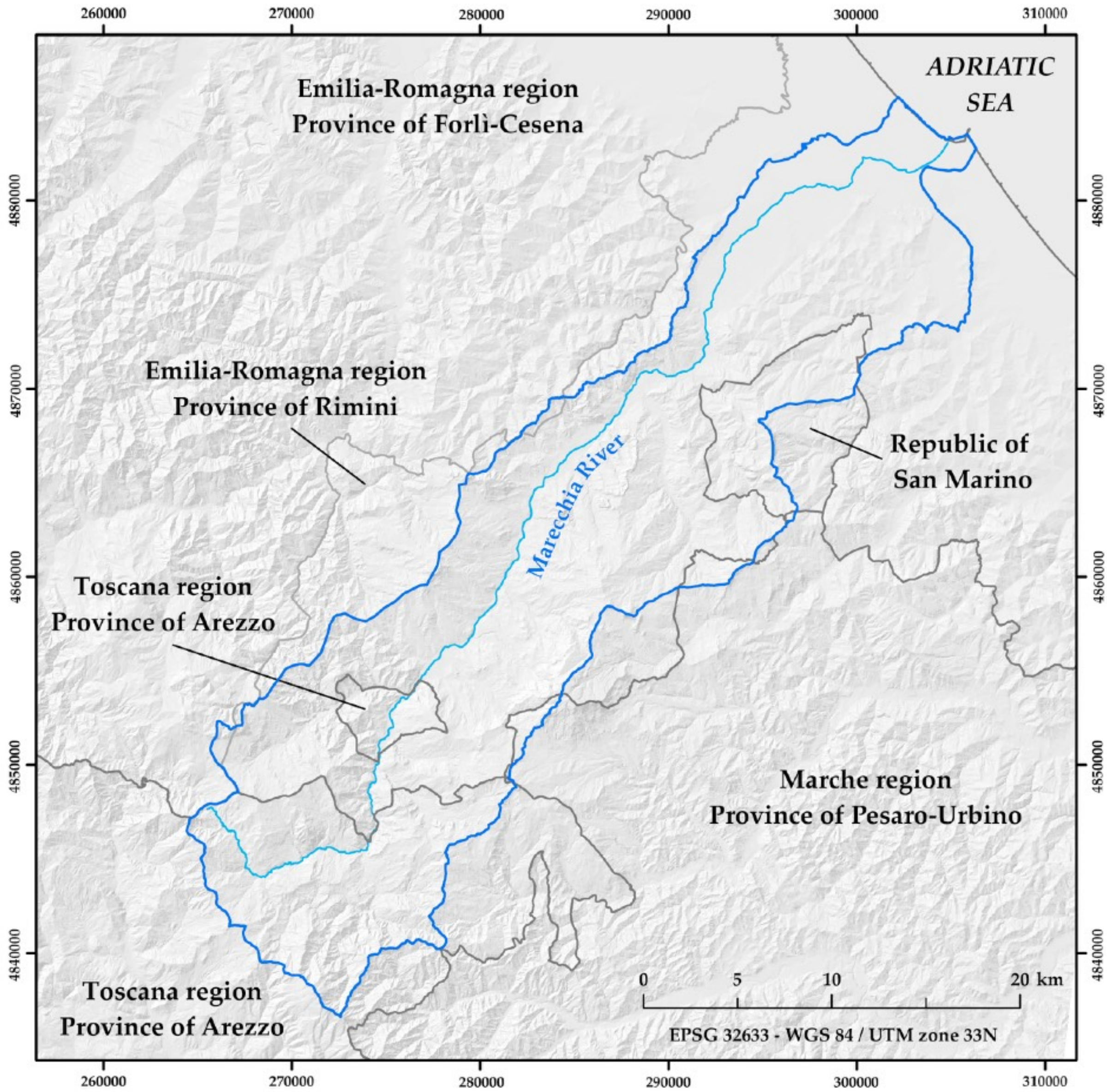

Figure 14. Administrative boundaries in corrispondence of the Marecchia River valley.

A similar referendum was held in June 2007 in the municipalities of Montecopiolo and Sassofeltrio. On both occasions, the referendum proposal was approved by a large majority, determining the passage from Marche to the Emilia-Romagna region.

This remarkably complex situation has led, over time, to dissimilarities at the cartographic level, for example, in the drafting of geological maps and geomorphological elements. This obstacle has been partially solved by the drawing up of the Geological Map of the Emilia-Romagna, Marche, Toscana and Umbria regions (Italy) at a scale of 1:250,000 (Conti et al., 2020). This contribution helps understand the study area's main geological and geodynamic characteristics. It has been used as a reference for the Geological map at a 1:50,000 scale, edited in the present research.

In the study area, an interesting action has been the establishment of a Strategic Plan, which focuses on activities in favour of the Marecchia Valley since 2013. It is promised to lead to a shared vision between all the municipalities of the valley "on the development of the whole territory, enhancing the natural, environmental, cultural, historical and identity heritage of the area and identifying a path for the creation of an integrated territorial product capable of competing on the market, starting with tourism, and generating well-being in terms of quality of life, social balance and economic sustainability"[12]. The actions also include a Contratto di Fiume (i.e., River Contract), an instrument dealing with the implementation of integrated planning policies focused on the interest of the natural environment, also through rehabilitation projects of river and lake basins (Bastiani M., 2011). It is a fundamental instrument to manage territories at a basin level that shares indispensable processes for the river catchment area and integration actions between different valley sectors. They help transition from sectoral and technocratic policies to ecological, fruition, and landscape requalification of river and lake basins integrated procedures, involving bodies of competence and the citizens as promoters and co-responsible custodians of this natural heritage (Bastiani M., 2011).

The institution of River Contracts in Italy is consequent to the second World Water Forum (L'Aja, 2000)[13], in which almost 6000 experts from more than a hundred different countries participated. The River Contracts fulfil essential assumptions of the legislation in force today, such as Directive 2000/60/CEE (Water Framework Directive), Directive 42/93/CEE (Aquatic Habitats Directive), Floods Directive

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[12] Memorandum of Understanding for the elaboration of the Strategic Plan and Valmarecchia River Contract http://www.fiumemarecchia.it/wp-content/uploads/Protocollo-CdF.pdf

[13] World Water Council website https://www.worldwatercouncil.org/en/hague-2000

2007/60/2007 and the Marine Strategy Framework Directive 2008/56/CEE, concerning environmental sustainability, the protection of marine ecosystems and the reduction of climate impacts, such as pollution and flood risk.

Essential objectives of the Marecchia River Contract are, in the field of Environmental quality and Landscape, the Bike Marecchia project for an integrated cycleway along the valley, the promotion of agriculture, cultivation systems and the ecosystem of the Marecchia valley, and the creation of a project dedicated to the identity landscape of this valley (Ridolfi et al., 2018). To evaluate the River Contract inside the broader Marecchia Valley Strategic Plan, a SWOT Analysis has been conducted as a tool that allows identifying strengths, weaknesses, opportunities and threats of the project. The critical aspects deriving from the analysis report are a perceivable ambiguity between those who believe that the Marecchia River is an element to be exploited and those who promote its enhancement and restoration (Sancisi G., 2020).

3.2 Geographical and geological constraints

Most of the Marecchia Valley belongs to the Emilia-Romagna region; it originates in the municipality of Badia Tedalda, in the Toscana region, and touches the far north of the Marche region, in the watershed municipalities of Carpegna and Monte Grimano Terme (PU). The Marecchia basin also includes part of San Marino territory, with the secondary valleys of the San Marino and Ausa creeks. The Marecchia valley is conventionally considered the natural border between northern and central Italy, including the neighbouring valleys of the Foglia and Tiber rivers. The main reliefs are Mt. dei Frati (1,453 m) and Mt. Maggiore (1,384 m), both part of the Alpe della Luna ridge, Mt. Carpegna (1,415 m) and Mt. Aquilone (1,354 m) in the Fumaiolo group.

The Marecchia valley originates in the municipality of Badia Tedalda, in Tuscany, from Mt. della Zucca (at 1,260 m), located between the Alpe della Luna and Mt. Fumaiolo. It flows for almost 70 km in a north-easterly direction until it reaches the extreme south-eastern edge of the Po Valley at the urban area of Rimini, where the river mouth is located. The river flows with an anti-Apennine orientation due to the antecedence of the main river pattern to the post-Pliocene rising of the chain (Zaghini, 1991). The Marecchia has the same course as the Apennine rivers of the Po Valley, with a north-eastern direction. The main settlements have historically developed on the rocky outcrops rising from the valley floor, such as Casteldelci, Pennabilli, Talamello, San Leo, Torriana, Verucchio, Santarcangelo di Romagna, and the smaller centres of Senatello, Petrella Guidi, Rocca Pratiffi, Molino di Bascio, Bascio, Scavolino, Soanne, Perticara. Some small villages, such as Ponte Messa, Novafeltria (formerly Mercatino Marecchia) and Villa Verucchio, develop along the valley floor.

The study area is marked by a unique geodynamical phenomenon, known as Valmarecchia thrust sheet or Valmarecchia Nappe (Spreafico et al., 2013). The main geological features of the area are represented, in fact, by the peculiar relationships between the allochthonous oceanic Ligurian Unit and the thick Neogene foredeep successions, representing the clastic wedge accompanying the later Alpine orogenic phase of the European and Adria plates collision (Argnani & Ricci Lucchi, 2001; Carmignani et al., 2004). The fascinating landscape of the Marecchia Valley is linked to its complex tectonic history. During the Miocene epoch, the right conditions were created for the establishment of carbonate platform sedimentation during the setting up of the Apennine chain. This occurred within different basins set above the Ligurian units as they migrated towards the Po valley foreland. At present, these deposits – called Epiligurian - appear to be dismembered into rigid plates and dominate the predominantly clayey Ligurian soils below.

In the study area lies a wide allochthonous body, known as Valmarecchia Nappe, that consists of stacked slices of Ligurian and Epiligurian rocks overthrusting Tuscan and Umbro-Marchean Units (Conti S., 1990, 1995; Conti et al., 2016; De Feyter A.J., 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 G., 1929; Capozzi et al., 1991; Cerrina Feroni et al., 1997; 2002; Conti et al., 1987; Ricci Lucchi F., 1986a; Selli R., 1954; Vai & 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 S., 1990), orthogonally to the main Apennine tectonic features. The Ligurian Units, characterised by argillitic clays, are the principal rocks responsible for translating the formations that lie above them, providing a preferential detachment zone to the migration that occurred during the Miocene uplift of the Apennine chain. Cornamusini et al., 2017 propose a complex mechanism for the emplacement of the Valmarecchia Nappe (Figure 19), which includes a

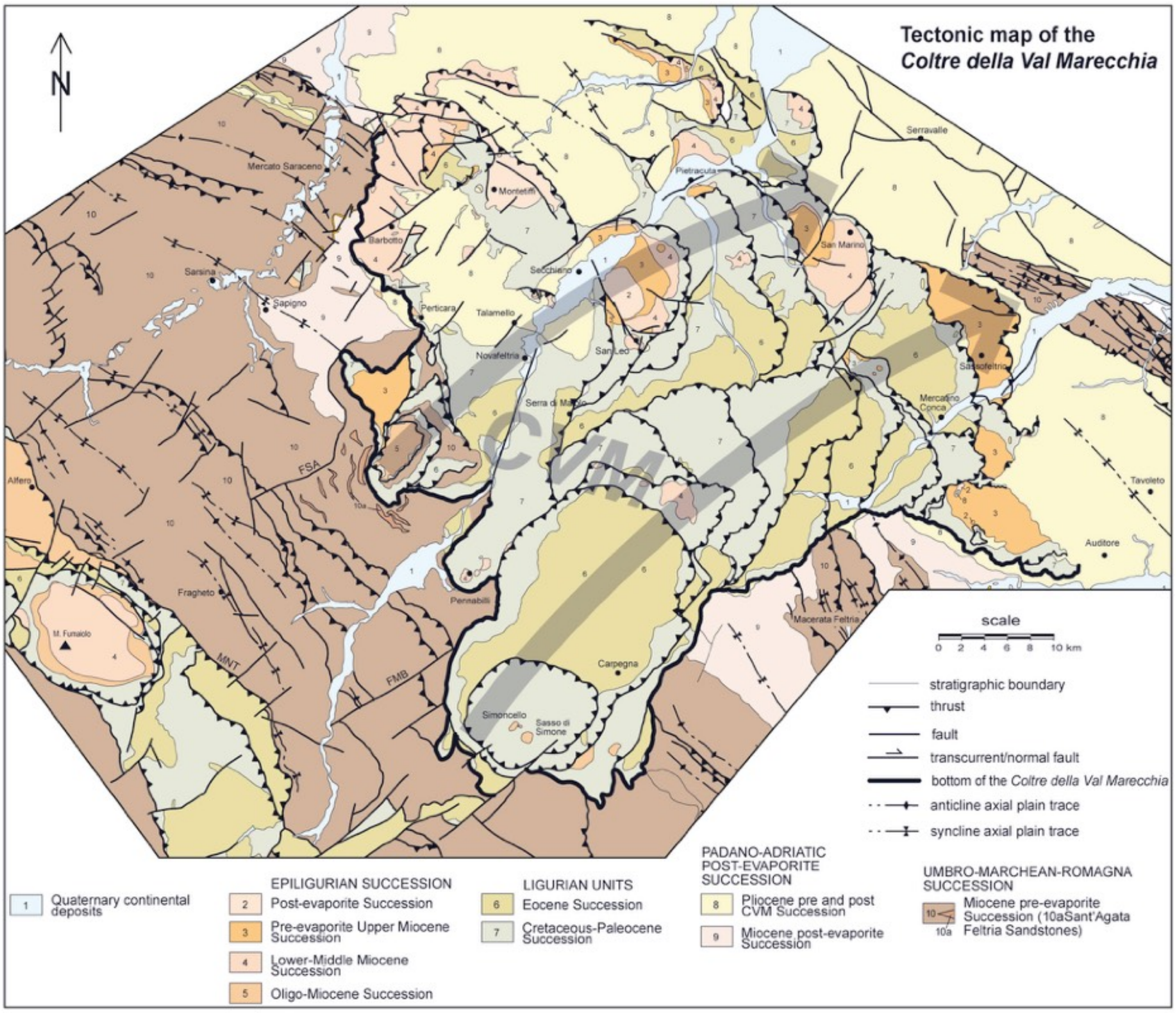

Figure 19. Tectonic map of the Valmarecchia Nappe. From Cornamusini et al., 2017.

tectonic origin due to the Mt. Nero Thrust and a submarine gravitational sliding development within the foredeep basin. This geological framework is characterised by a complex setting, organised in stratigraphic-tectonic units, of which the Valmarecchia Nappe is part (Cornamusini et al., 2017).

The two main stratigraphic–structural complexes, representative of sedimentary successions belonging to different paleogeographic domains are:

- the autochthonous Umbro-Marchean-Romagna Pre-Evaporite Succession and the Padano-Adriatic Post-Evaporite Succession, ascribed to the late Burdigalian–early Messinian and to the late Messinian–Pleistocene, respectively (Marnoso-Arenacea formation, Gessoso-Solfifera formation, Argille Azzurre formation, Arenarie di Monte Perticara formation);

- the allochthonous Valmarecchia Nappe formed by a strongly deformed Cretaceous-Tertiary succession, the Ligurian Unit (Argille Varicolori formation, Arenarie di Monte Borello formation) and by an unconformable overlying less deformed Eocene-earliest Pliocene semi-allochthonous (sensu Ricci Lucchi F., 1987) succession called the 'Epiligurian Succession' (San Marino formation, Acquaviva formation, Monte Fumaiolo formation).

Based on the stratigraphic and tectonic relationships with the Valmarecchia Nappe, the autochthonous successions can be divided in a portion underlying (Burdigalian to late Messinian for the northwestern area and to early Pliocene for the eastern area) and in a portion overlying the Valmarecchia Nappe (early-middle Pliocene to Pleistocene) (Cornamusini et al., 2017).

The autochthonous succession is deposited in a vast and complex foredeep basin system (Argnani & Ricci Lucchi, 2001; Ricci Lucchi F., 1986a; Tinterri & Tagliaferri, 2015), whereas the allochthonous Ligurian Unit represents the deformed orogenic wedge, and the Epiligurian Succession deposited in a thrust-top basin system (Ricci Lucchi, 1986a). The Umbro-Marchean-Romagna Succession consists of Upper

Burdigalian to Messinian turbiditic sandstones and marls, sedimented in foredeep basins and divided into two thrusted portions, an inner (Late Burdigalian to Messinian) and an outer (Tortonian to Late Messinian) one. The wide inner basin was infilled by classical turbidite systems of the Romagna Marnoso-arenacea formation, whereas differently the outer basin consists of minor turbidite depocenters, the so-called 'minor molasse basins' (Cantalamessa et al., 1986; Centamore et al., 1978; Ricci Lucchi, 1986a), characterising the Marchean Marnoso-arenacea formation The Padano-Adriatic Post-Evaporite Succession consists of deposits subsequent to the Messinian salinity crisis, Late Messinian to Early Pleistocene in age, and unconformably lay above the Umbro-Marchean-Romagna Succession. The separating unconformity has regional significance and is linked with the intra-Messinian tectonic phase and sea-level drop (Roveri et al., 1998; Vai & Castellarin, 1992; Zattin et al., 2002).

The allochthonous Ligurian Unit is structured in tectonic slivers with the less deformed semi-allochthonous unit (Epiligurian Succession) on top. The thick slivers forming the Valmarecchia Nappe are enclosed in two distinct main autochthonous depositional units: the Messinian deposits (Ghioli di Letto formation) and the Pliocene deposits (Argille Azzurre formation). The Ligurian Unit formations span from Early Cretaceous to Middle Eocene for the Marecchia Valley (Cornamusini et al., 2017).

During its tectonic translation, the Epiligurian Succession is indicated as semi-allochthonous, unconformably deposited in satellite or piggy-back basins on the top of the allochthonous Ligurian Unit toward the foreland (Ricci Lucchi, 1986b). In the Marecchia Valley, it testifies to the timing of the allochthonous Ligurian thrust sheet and ranges with formations spanning from the Oligocene until the earliest the Pliocene. It shows some internal angular unconformities due to the active syn-sedimentary tectonics, typical of the satellite basins, subdividing it in depositional sequences (Ricci Lucchi, 1986b; Conti et al., 2016). Finally, the Quaternary alluvial and littoral deposits lay unconformably on the older units.

The following simplified classification derives from the recently published cartography of Emilia-Romagna, Marche, Toscana and Umbria regions at 1:250,000 scale, mentioned above (Conti et al., 2020).

1. Cervarola-Falterona Succession

- CFfa - turbidite sandstones, siltstones, shales and marlstones, with olistostromes: Verghereto Marls (Aquitanian – Burdigalian); Villore Varicolored Marls (Rupelian – Aquitanian);

- CFvc - marlstones, silty marlstones and siltstones, with interbedded sandstones: Vicchio formation (Late Aquitanian – Langhian);

2. External Ligurian Domain (outer succession)

- ELel - helminthoides flysch: limestones, marly limestones, marlstones, shales: Monte Morello formation (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 – Ypresian).

3. Epiligurian succession (pre-evaporitic)

- EPbs sandstones, calcarenites, claystones, conglomerates, breccias and olistostromes: Monte Fumaiolo formation, Monte Aquilone member, della Vetta member (Late Burdigalian – Serravallian); San Marino formation (Late Burdigalian – Early Langhian);

- EPra turbidite sandstones, marlstones, shales, breccias: Complesso della Valle del Savio (Middle Eocene – Late Oligocene);

4. Quaternary continental deposits

- Qa1 alluvial fan and terraced deposits: Ravenna Subsynthem (Late Pleistocene - Holocene); Modena Unit (IV-VI century AD – present day);

5. 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).

3.3 Geomorphological settings

Most of the landforms of the elevated areas of Valmarecchia and Montefeltro territories show a robust control by the litho-structural arrangement of the Valmarecchia Nappe, stressing both the lack of simple geometric arrangements in the geologic structure itself and the effect of rocks of different resistance to degradation and erosion processes (clays, arenites, limestones).

The presence of resistant rock plates embedded in clayey terrains advantage the processes of selective erosion, originating steep cliffs. The clayey bedrocks undermine more resistant rock plates, with the consequent retreat of their borderline cliffs and extensive shaping of hillsides by mass movements or vast badlands (Nesci et al., 2005), or the development of rills and gullies on areas that are naturally poorly vegetated or affected by agricultural work. The rocky slabs are tectonised and show complex systems of faults and joint sets that contribute to the consisting phenomenon of lateral spreading, consistent throughout the valley and the leading cause of topples, tilting and rockfalls. Landslides of the earth flow and slide type are widespread, and interest the underlying clayey formations, involved in plastic movements (Casagli N., 1994). The high deformability contrast between the calcareous wedge and the underlying clays is the leading cause of this instability (D'Ambra et al., 2004), together with the structural setting of the rock slabs, the flow of groundwater inside them, its consequent influence on basal clays, and creep phenomena inside the clays. These processes determine the opening and progressive widening of sub-vertical fractures in the calcareous blocks (Spreafico et al., 2015).

Along with the described processes, the other main geomorphological features are found in fluvial dynamics. Fluvial terraces are widespread mainly in the middle and lower portions of the valley, and aggradation or incisive phenomena are common.

In the uppermost part of the valley, the Marecchia River cuts the Marnoso-Arenacea formation with a typical "V" shape, similar to the contiguous valley of the Savio River. In the middle portion of the valley, starting from Pennabilli towards Ponte Verucchio, the Ligurian and Epiligurian formations outcrop, and an alternation of narrow and large portions of the riverbed can be found, related to the outcropping lithotypes of respectively lower or higher erodibility.

The main hydraulic bottlenecks are found in correspondence with Ponte Molino Baffoni, Ponte Santa Maria Maddalena and Ponte Verucchio localities, where deposition phenomena are observed upstream and erosion downstream of each point. Downstream of Ponte Verucchio, formations belonging to the Pliocene era outcrop and most of the terraced alluvium of the Marecchia River are found.

From the analysis of the river network, it can be observed that in the upper part of the valley, the Marecchia River flows towards its hydrographic right and then passes in a pronounced way towards its left, thus allowing more significant development of the right tributaries (such as Presale, Torbello, Messa, Prena, Mazzocco and San Marino creeks). The course of the hydrographic network, i.e. its hydrographic pattern, varies from dendritic to sub-dendritic in the mountainous section, in correspondence to the outcrops of the Marnoso-Arenacea formation. In contrast, in the middle part of the valley, pinned or combed patterns prevail in correspondence to the outcrops of Ligurian clayey lithotypes. Finally, a sub-parallel and angled pattern can be observed in correspondence with the outcrops of the Epiligurian limestone units, in some cases in relation to tectonic lineaments.

3.4 Geosites and Geoheritage

Considering the current scenario about natural heritage protection, conservation, and promotion, geomorphological heritage and geomorphosites could represent a shared value to most of the geosites of the study area. They could be a starting point for a series of proposals and actions aiming to preserve and share knowledge about natural and cultural heritage as a whole.

When defining heritage geomorphology and its associated practices, some authors state that the geomorphologist dealing with geomorphosites and heritage must be polyvalent. They should master all branches of geomorphology. Because geomorphosites present additional values related to aesthetics, human history, and culture, they should also be open to the issues associated with human and cultural geography, and connect these competencies to geomorphology (Coratza & Hobléa, 2018). According to Panizza & Piacente, 2003, cultural geomorphology is, by definition, the discipline that studies the geomorphological component of a territory which embodies both a cultural feature of the landscape and its interactions with cultural heritage (archaeological, historical, architectonic, etc.).

The Marecchia River valley happens to count several geosites established by the Emilia-Romagna region. Their extent sometimes overlaps those of SIC-ZSC or PS Natura 2000 protected areas and Natural Parks or Reserves; this factor determines the protection status of the site. The Interregional Natural Park of Sasso Simone and Simoncello (Emilia-Romagna and Marche regions competence) and part of the homonymous Natural Reserve (Toscana competence) fall within the study area and represent a natural heritage with a solid geological character for the whole area.

The study area comprehends 15 regional relevance geosites and 19 local relevance geosites established by the Emilia-Romagna region. A geomorphological interest can be identified as a scientific interest for most geosites, constituting a distinctive feature. Furthermore, many of the existing geosites can be assessed with an aesthetic dimension, a dynamic dimension, and the imbrication of scales. These characteristics would make them suitable for a geomorphosite titling (Reynard et al., 2009) and underline them as unique types of geoheritage.

The Marecchia valley includes part of the territory of the Republic of San Marino, which is inscribed between the Emilia-Romagna and Marche regions. San Marino is the third smallest of the European microstates and the oldest Republic in the world.

About the protection and enhancement of the geological Heritage, San Marino intervened as early as 1995 with the *Legge Quadro per la Tutela dell'Ambiente e la Salvaguardia del Paesaggio, della Vegetazione e della Flora* (Framework Law for the Protection of the Environment and the Safeguarding of the Landscape, Vegetation and Flora, *Dicastero al Territorio e Ambiente*, Department of Land and Environment; n. 126/95), in which protected areas are listed as follows:

a) the protected naturalistic areas, meaning those parts of the territory of landscape or environmental importance with characteristics of naturalness or conservationist integration;

b) the park areas, meaning areas that, constituting general public interest for the community, are organised in a unitary way, with preeminent regard to the needs of protection of nature and the environment, for cultural and recreational use, agroforestry, and other activities to promote the cultural, social and economic growth of the community;

c) nature reserves, understood as representative areas of critical natural components, within the scale of variation found in the ecosystems of the territory. These areas, in addition to the conditions referred to in paragraph a), have more specific characteristics of diversity, representativeness, fragility, and spectacularity;

d) the integral natural reserves, intended as parts of the territory of particular and relevant naturalistic and scientific interest with characteristics of rarity, relictuality or typicality, relative to vegetal, zoological, geomorphological, and hydrogeological manifestations;

e) the agricultural areas, as parts of the territory intended for the development of agriculture and environmental protection, as well as landscape conservation;

f) the gully areas, or badlands, as particular geomorphological evidence of the territory within the perceptive framework of the landscape;

g) the landscape emergencies, understood as parts of the territory in which the relationships between buildings, fields, and natural vegetation constitute systems of particular cultural interest and significant historical or landscape importance;

h) the urban green areas, as parts of the territory responsible for the protection and qualification of urban areas and promoting social and recreational purposes.

Notably, geomorphological elements such as gullies and badlands are directly mentioned as peculiar environments that require protection.

In 2010, the *Piano Particolareggiato Delle Aree Naturalistiche Tutelate* (Comprehensive Plan of Protected Naturalistic Areas) was promoted to protect and enhance the natural areas of the Republic and approved by the *Segreteria di Stato al Territorio ed Ambiente* (Secretary of State for Territory and Environment). The Plan delimited and established large protected areas in which a series of geological or geomorphological emergencies are included. The latter have been qualitatively considered in the present research, although it has not been given a quantitative evaluation of scientific and additional values. The Emilia-Romagna criteria for selecting geosites (which has been applied also for the newly proposed ones) is different from the one adopted for San Marino geosites. These latter are not only much smaller in size, but they identify contiguous areas as different geosites. On the contrary, the Emilia-Romagna catalogue comprehends bigger geosites, in which several landforms coexist in shaping the different values that can be assessed. The quantitative assessment would thus be invalidated by the fundamental differences between the two methods of identification.

In addition to the already existing ones, newly proposed geosites have been proposed to enhance valuable areas in terms of geological knowledge and/or dissemination and are listed as follows:

- Rimini town: an urban geomorphosite that enhances the relationship among geomorphological elements and evolution of the historical city;
- Covignano hill: a geosite where Pliocene sands hosted one of the first settlements of Italian prehistory, from 800,000 years BP;
- Ponte Santa Maria Maddalena boulders: an unusual river trait where massive calcareous blocks can be found in the narrow riverbed;
- Petrella Guidi boulder: a medieval town rising upon an erratic calcareous boulder floating on the clayey formations;
- Maciano hill: a geosite where the history of castellation is related with landslides;
- Scavolino palaeo-lake: a rare example of anthropic environmental modifications that dates back to the XVII century;
- Rocca Pratiffi boulder: another example of settlement upon a calcareous boulder, migrating over the clayey formations below;
- Pietrafagnana mount: a suggestive and mysterious location where conglomerates of Messinian age outcrop;
- Pietrarubbia mount: the outcropping of the same Messinian reddish conglomerates gave name to the village that was settled upon them.

Newly proposed geological points of interest are also the so-called *Vasche rupestri della Valmarecchia* (i.e., Valmarecchia rupestrian tubs), as an example of those features and objects which can be interpreted as a part of the geological heritage, even if they are not purely geological (Wetzel L.R., 2002; Erikstad L., 2013; Gray M., 2013; Lubova et al., 2013; Bruno et al., 2014). Regarding these aspects, the Valmarecchia rupestrian tubs constitute an original example of an interaction between geology and anthropic activities, consisting of tanks or flat surfaces carved on isolated boulders or mountain peaks. The first written testimonies describing rupestrian tubs in Valmarecchia date to 1957. Their origin is considered ancient (until protohistoric), but no absolute dating is available. Their usage has probably been discontinuous throughout the centuries (Battistini and Battistini, 2011), and a functional purpose related to water storage can be assumed (i.e., Pope's seat), especially for those grouped in complexes (i.e., Pennarossa tubs). They can be cut in different shapes (i.e., open tubs or beds, single tubs, double tubs), and various interpretations have been proposed for their usage (Battistini and Ravara Montebelli, 2011). The well-known examples of rupestrian tubs have been mapped with the addition of new points of interest in the Republic of San Marino area or in correspondence with simpler structures not already investigated.

The study area comprehends different kinds of geomorphosites, from badlands on clays to rockfalls on limestone, from debris flows to non-karst gravity-induced caves, and from mining sites to riverbed modifications. Different erosion velocities and patterns create micro-landscapes in the landscape, observable at different scales of time and space, that allow new fruition of geological concepts. Natural phenomena and processes are more easily recounted thanks to their strict connection to human time and actions. They can be proposed to a broad public as the result of the relationship between humanity and nature through history.

Chapter 4.

Geosites qualitative and quantitative assessment

Investigations on geosites and geomorphosites (i.e., the elements of the geological heritage) constitute an innovative area of research in Earth Sciences. They are considered indispensable elements in territorial planning for the sustainable management of the environment (Bollati et al., 2018).

Several methodologies for mapping and assessing sites of geomorphological interest have been developed in recent times (Carton et al., 2015; Coratza & Regolini-Bissig, 2009; Pelfini & Bollati, 2014; Reynard et al., 2016; Bollati et al., 2017; Bouzerkraoui et al., 2018; Mucivuna et al., 2019); geomorphosites hold a certain complexity and many meanings inside them, thus requiring specific cartography and methods for their representation.

For the present research, the geosites established by the Emilia-Romagna region and the proposed geosites have been quantitatively assessed following Reynard et al., 2016 method, which has been selected as the most suitable for the qualitative and quantitative assessment of existing geosites, for most of them can be considered geomorphosites (38 out of 43 of the Emilia-Romagna and proposed geosites, 8 out of 25 of the Republic of San Marino geosites).

According to the indications of ISPRA's guidelines for geomorphological mapping (Campobasso et al., 2018), geosites that satisfy the requirements of geomorphosites have been highlighted in the *Geomorphological map* with a golden-yellow border along their perimeter.

4.1 Reynard et al., 2016 methodology

In the broad context of geoheritage inventory, assessment, protection and promotion, active in the last 35 years, many methodologies concerning geomorphosites have been experimented and carried out with different goals and at different scales (Rivas et al., 1997; Grandgirard V., 1999; Bonachea et al., 2005; Coratza & Giusti, 2005; Pralong J.P., 2005; Serrano & González Trueba, 2005; Reynard et al., 2007; Pereira et al., 2007; Zouros N., 2007; Feuillet & Sourp, 2010; Comănescu et al., 2012; Kubalíková, L., 2013; Brilha J., 2015; Reynard et al., 2016; Mucivuna et al., 2019). Reynard et al., 2016 has been considered the most suitable method for the present research. It is a comprehensive procedure based on previous research and adapted for the specificities of geomorphological heritage, which in turn constitute a characteristic trait of the Marecchia valley.

The method consists of inventory and management indications suitable for large areas of study. Its approach is divided into two main stages for each indication: the selection and assessment of geomorphosites (inventory) and management and use of geomorphosites and evaluation by users (management).

Both these steps have been performed in the study area, with the existing geosites established by the Emilia-Romagna region as a starting point, the addition of new proposed geomorphosites, the quantitative assessment of these two groups, the experimentation of valorisation activities in some exemplary geomorphosites and the evaluation of the perception of the same sites by users.

Every geosite has been assigned with a distinctive code consisting of 3 capital letters referring to the portion of the study area (VML = lower Valmarecchia; VMM = middle Valmarecchia; VMU = upper Valmarecchia; MTF = Montefeltro historical region; RSM = Republic of San Marino), 3 lowercase letters defining the main process, features or distinctive characteristics of the geosite or geomorphosite (mar = marine; ant = anthropic; flv = fluvial; cav = cavities; rel = relief; mmv = mass movements; kar = karst or pseudo-karst; min = mines; lac = lacustine; str = stratigraphic; tec = tectonics; fos = fossils; cha = chalks; rup = rupestrian evidence) and, finally, 3 digits indicating a progressive number referred to the process or features.

Additionally, a code has been assigned to each geosite or geomorphosite, referring to the degree of urbanisation or anthropogenic changes. The code means to highlight the correlation between the site and human footprint, and can be:

- NAT = natural, none or very little human frequentation of the site;
- SN = semi-natural, little human print (for instance, rural villages environment) or abandonment of the site in historical times;
- SU = semi-urban, considerable human print that led to the current environment, with possible alteration of previous landforms (i.e., Middle Ages castle sites);
- URB = urban, human activities of high impact performed with temporal continuity, which has altered or erased previously existing landforms;
- RUP = rupestrian, related to cultual or functional rock carving, difficult to date.

4.2 Quantitative assessment

According to the selected method, a quantitative assessment of the intrinsic value of the geosites and geomorphosites has been compiled, focusing on both their central (i.e., scientific) and additional values.

Scientific value is expressed as the criteria IN (Integrity), RE (representativeness), RA (rareness) and PI (palaeogeographic interest). The results of this assessment are reported in Table 2.

Additional values are the following:

- Ecological value (EV): arithmetic mean among criteria Ecological Impact (EI) and Protected Site (PS) - Table 3;
- Aesthetic value (AV): arithmetic mean among criteria Viewpoints (VP) and Colour contrast, Vertical development, Space structuration (CVS) - Table 4;

- Cultural value (CV): highest score among Religious Importance (RI), Historical Importance (HI), Artistic and Literary Importance (AL), Economic Importance (EC) - Table 5.

The values have been assigned with a score from 0 to 1. The resulting ratings have been summed up to get a quantitative expression of the comprehensive quality of each geosite or geomorphosite (Table 6).

The protection status of each site has been evaluated considering their insistence on SIC-ZSC or ZPS protected areas and on Natural Parks or Reserves. They have been reported in Table 6.

The quantitative assessment of the central and additional values of the Valmarecchia and Montefeltro geosites and geomorphosites had never been done before. It allowed the development of considerations regarding the priority of conservation and enhancement of the analysed geosites.

Several observations can be made from the results in Table 5. Firstly, all the sites that obtained the highest scores (i.e., Total score > 3.50; Torriana and Montebello peaks, Tausani cliff, San Leo cliff, Mt. Pincio, Perticara and Mt. Aquilone, San Leo cliff, Maiolo cliff and badlands, Mt. Ercole and Mt. San Silvestro, Mt. Carpegna, Pietrarubbia mount, Mt. Fumaiolo, Miratoio peak and Sasso Simone and Simoncello) occur to be insisting on protected areas, thus representing optimal possibilities for geoconservation and, more generally, for actions of valorisation or enhancement.

The sites which obtained a score very close to the possible maximum of 4 points are represented by Mt. Pincio, Perticara and Mt. Aquilone (3.84), Maiolo cliff and badlands (3.82), Mt. Carpegna (3.90), Mt. Fumaiolo (3.94) and Sasso Simone and Simoncello (3.94), which represent in turn a sum of the main geological and geomorphological features of the whole Marecchia valley.

Precisely, Maiolo cliff and badlands and Sasso Simone and Simoncello have been chosen as destinations for the geologically themed excursions of this research, while Mt. Fumaiolo has been enhanced through a dedicated study and presentation for the Oxford Geoheritage Virtual Conference (OxGVC) held in May 2020.

Geosite			Scientific value (SV)				
Nr	**Code**	**Name**	**IN**	**RE**	**RA**	**PI**	**Total**
1	VMLmar001	Coastal palaeo-sea cliff	0.25	0.5	0.75	1	**0.63**
2	VMLhum001	Rimini town	0.25	1	0.75	0.75	**0.69**
3	VMLflv001	Marecchia river mouth	0.75	0.25	0.25	0.75	**0.50**
4	VMLcav001	Covignano hill	0.75	0.75	0.5	0.75	**0.69**
5	VMLcav002	Santarcangelo caves	0.75	1	0.75	0.75	**0.81**
6	VMLflv002	Ponte Verucchio canyon	0.75	1	1	0.5	**0.81**
7	VMMhum002	San Giovanni in Galilea quarry	0.25	0.75	0.5	0.75	**0.56**
8	VMMrel001	Verucchio peak	0.75	1	0.75	0.75	**0.81**
9	VMMrel002	Torriana and Montebello peaks	1	1	0.75	0.75	**0.88**
10	VMMrel003	Speco cliff	1	1	0.75	0.75	**0.88**
11	VMMrel004	Mt. Matto, Mt. del Ronco and Mt. la Costa	1	0.75	0.5	0.75	**0.75**
12	VMMrel005	Pietracuta peak	0.75	1	1	0.75	**0.88**
13	VMMhum003	Mt. Ceti quarry	0.25	0.75	0.5	0.75	**0.56**
14	VMMmmv001	Ponte Santa Maria Maddalena boulders	1	1	1	0.75	**0.94**
15	VMMrel006	Tausani cliff	1	1	1	0.75	**0.94**
16	VMMrel007	Montemaggio hill	0.75	0.5	0.5	0.75	**0.63**
17	VMMkar001	Legnagnone chalks	1	1	0.75	1	**0.94**
18	VMMrel008	Mt. Pincio, Perticara and Mt. Aquilone	1	1	0.75	0.75	**0.88**
19	VMMmmv002	San Leo cliff	1	1	1	0.75	**0.94**
20	VMMmmv003	Maiolo cliff and badlands	1	1	1	0.75	**0.94**
21	VMMmin001	Perticara mines	0.75	1	1	1	**0.94**
22	VMMkar002	Sapigno syncline	0.75	1	1	1	**0.94**
23	VMUmmv004	Mt. Ercole and Mt. San Silvestro	1	1	0.75	0.75	**0.88**
24	VMUrel009	Mt. San Marco peak	1	1	1	0.75	**0.94**
25	VMUrel010	Petrella Guidi boulder	1	0.75	0.75	0.75	**0.81**
26	VMUmmv005	Maciano hill	1	0.75	0.75	0.75	**0.81**
27	VMUlac001	Scavolino palaeo-lake	1	1	1	0.75	**0.94**
28	VMUmmv006	Mt. Carpegna	0.75	1	1	1	**0.94**
29	VMUrel011	Rocca Pratiffi boulder	1	0.75	0.75	0.75	**0.81**
30	VMUmmv007	Pennabilli mounts	0.75	1	0.75	0.75	**0.81**
31	VMUstr001	Senatello-Marecchia confluence anticline	1	1	1	0.75	**0.94**
32	VMUstr002	Casteldelci cliff	1	1	0.5	0.75	**0.81**
33	VMUstr003	Mt. Faggiola Vecchia and Mt. Faggiola Nuova	1	0.75	0.5	0.75	**0.75**
34	VMUtec001	Sant'Alberico's intra-mountain basin	1	0.5	0.75	1	**0.81**
35	VMUflv003	Senatello springs	1	0.75	0.5	0.75	**0.75**
36	MTFstr004	Pietrafagnana mount	0.75	1	1	1	**0.94**
37	MTFstr005	Pietrarubbia mount	0.75	1	1	1	**0.94**
38	VMUflv004	Tevere springs	1	1	0.5	0.75	**0.81**
39	VMUmmv008	Mt. Fumaiolo	1	1	1	0.75	**0.94**
40	VMUstr006	Molino di Bascio cliff	1	0.75	1	0.75	**0.88**
41	VMUcav003	Miratoio peak	1	0.75	1	0.75	**0.88**
42	VMUmmv009	Sasso Simone and Simoncello	1	1	1	0.75	**0.94**
43	VMUflv005	Marecchia springs	1	1	0.5	0.75	**0.81**

Table 2. Scientific value assessment for Valmarecchia and Montefeltro geosites.

Geosite			Ecological value (EV)		
Nr	**Code**	**Name**	**EI**	**PS**	**EV**
1	VMLmar001	Coastal palaeo-sea cliff	0.25	0	**0.13**
2	VMLhum001	Rimini town	0.25	0	**0.13**
3	VMLflv001	Marecchia river mouth	0.25	0	**0.13**
4	VMLcav001	Covignano hill	0.50	0	**0.25**
5	VMLcav002	Santarcangelo caves	0.50	0	**0.25**
6	VMLflv002	Ponte Verucchio canyon	0.50	1	**0.75**
7	VMMhum002	San Giovanni in Galilea quarry	0.25	0	**0.13**
8	VMMrel001	Verucchio peak	0.75	0	**0.38**
9	VMMrel002	Torriana and Montebello peaks	0.75	1	**0.88**
10	VMMrel003	Speco cliff	0.75	1	**0.88**
11	VMMrel004	Mt. Matto, Mt. del Ronco and Mt. la Costa	0.75	1	**0.88**
12	VMMrel005	Pietracuta peak	0.75	0	**0.38**
13	VMMhum003	Mt. Ceti quarry	0.25	0	**0.13**
14	VMMmmv001	Ponte Santa Maria Maddalena boulders	0.50	0	**0.25**
15	VMMrel006	Tausani cliff	1	0.75	**0.88**
16	VMMrel007	Montemaggio hill	0.75	0	**0.38**
17	VMMkar001	Legnagnone chalks	1	0.75	**0.88**
18	VMMrel008	Mt. Pincio, Perticara and Mt. Aquilone	1	1	**1**
19	VMMmmv002	San Leo cliff	0.75	0.75	**0.75**
20	VMMmmv003	Maiolo cliff and badlands	0.75	1	**0.88**
21	VMMmin001	Perticara mines	0.75	0.75	**0.75**
22	VMMkar002	Sapigno syncline	0.75	0.75	**0.75**
23	VMUmmv004	Mt. Ercole and Mt. San Silvestro	0.75	1	**0.88**
24	VMUrel009	Mt. San Marco peak	0.50	0	**0.25**
25	VMUrel010	Petrella Guidi boulder	0.50	0	**0.25**
26	VMUmmv005	Maciano hill	0.50	1	**0.75**
27	VMUlac001	Scavolino palaeo-lake	0.75	1	**0.88**
28	VMUmmv006	Mt. Carpegna	1	1	**1**
29	VMUrel011	Rocca Pratiffi boulder	0.75	0	**0.38**
30	VMUmmv007	Pennabilli mounts	0.75	0	**0.38**
31	VMUstr001	Senatello-Marecchia confluence anticline	0.75	0.75	**0.75**
32	VMUstr002	Casteldelci cliff	1	0	**0.50**
33	VMUstr003	Mt. Faggiola Vecchia and Mt. Faggiola Nuova	0.75	0	**0.37**
34	VMUtec001	Sant'Alberico's intra-mountain basin	0.75	1	**0.88**
35	VMUflv003	Senatello springs	0.75	0.25	**0.50**
36	MTFstr004	Pietrafagnana mount	0.75	1	**0.88**
37	MTFstr005	Pietrarubbia mount	0.75	1	**0.88**
38	VMUflv004	Tevere springs	0.75	1	**0.88**
39	VMUmmv008	Mt. Fumaiolo	1	1	**1**
40	VMUstr006	Molino di Bascio cliff	0.75	0	**0.38**
41	VMUcav003	Miratoio peak	1	1	**1**
42	VMUmmv009	Sasso Simone and Simoncello	1	1	**1**
43	VMUflv005	Marecchia springs	0.75	0	**0.37**

Table 3. Ecological value assessment for Valmarecchia and Montefeltro geosites.

Geosite			Aesthetic value (AV)		
Nr	**Code**	**Name**	**VP**	**CVS**	**AV**
1	VMLmar001	Coastal palaeo-sea cliff	0.25	0.08	**0.17**
2	VMLhum001	Rimini town	0.25	0.08	**0.17**
3	VMLflv001	Marecchia river mouth	0.25	0.17	**0.21**
4	VMLcav001	Covignano hill	0.50	0.50	**0.50**
5	VMLcav002	Santarcangelo caves	0.25	0.50	**0.38**
6	VMLflv002	Ponte Verucchio canyon	0.50	0.75	**0.63**
7	VMMhum002	San Giovanni in Galilea quarry	0.75	0.83	**0.79**
8	VMMrel001	Verucchio peak	0.75	0.75	**0.75**
9	VMMrel002	Torriana and Montebello peaks	1	0.83	**0.92**
10	VMMrel003	Speco cliff	0.75	0.75	**0.75**
11	VMMrel004	Mt. Matto, Mt. del Ronco and Mt. la Costa	0.75	0.75	**0.75**
12	VMMrel005	Pietracuta peak	0.75	0.83	**0.79**
13	VMMhum003	Mt. Ceti quarry	0.75	0.83	**0.79**
14	VMMmmv001	Ponte Santa Maria Maddalena boulders	0.25	0.58	**0.42**
15	VMMrel006	Tausani cliff	1	0.92	**0.96**
16	VMMrel007	Montemaggio hill	0.5	0.83	**0.67**
17	VMMkar001	Legnagnone chalks	0.5	0.58	**0.54**
18	VMMrel008	Mt. Pincio, Perticara and Mt. Aquilone	1	0.92	**0.96**
19	VMMmmv002	San Leo cliff	1	0.92	**0.96**
20	VMMmmv003	Maiolo cliff and badlands	1	1	**1**
21	VMMmin001	Perticara mines	0.5	0.83	**0.67**
22	VMMkar002	Sapigno syncline	0.75	0.67	**0.71**
23	VMUmmv004	Mt. Ercole and Mt. San Silvestro	1	0.92	**0.96**
24	VMUrel009	Mt. San Marco peak	1	0.92	**0.96**
25	VMUrel010	Petrella Guidi boulder	1	0.75	**0.88**
26	VMUmmv005	Maciano hill	0.75	0.67	**0.71**
27	VMUlac001	Scavolino palaeo-lake	0.75	0.58	**0.67**
28	VMUmmv006	Mt. Carpegna	1	0.92	**0.96**
29	VMUrel011	Rocca Pratiffi boulder	1	0.75	**0.88**
30	VMUmmv007	Pennabilli mounts	1	0.83	**0.92**
31	VMUstr001	Senatello-Marecchia confluence anticline	0.5	0.67	**0.58**
32	VMUstr002	Casteldelci cliff	1	0.92	**0.96**
33	VMUstr003	Mt. Faggiola Vecchia and Mt. Faggiola Nuova	1	0.75	**0.88**
34	VMUtec001	Sant'Alberico's intra-mountain basin	0.75	0.66	**0.71**
35	VMUflv003	Senatello springs	0	0.83	**0.42**
36	MTFstr004	Pietrafagnana mount	0.75	0.75	**0.75**
37	MTFstr005	Pietrarubbia mount	0.75	0.75	**0.75**
38	VMUflv004	Tevere springs	0.50	0.58	**0.54**
39	VMUmmv008	Mt. Fumaiolo	1	1	**1**
40	VMUstr006	Molino di Bascio cliff	1	0.75	**0.88**
41	VMUcav003	Miratoio peak	1	0.92	**0.96**
42	VMUmmv009	Sasso Simone and Simoncello	1	1.00	**1**
43	VMUflv005	Marecchia springs	0.25	0.50	**0.38**

Table 4. Aesthetic value assessment for Valmarecchia and Montefeltro geosites.

Geosite			Cultural value (CV)				
Nr	**Code**	**Name**	**RI**	**HI**	**AL**	**EC**	**CV**
1	VMLmar001	Coastal palaeo-sea cliff	0	0	1	0	**1**
2	VMLhum001	Rimini town	1	1	1	1	**1**
3	VMLflv001	Marecchia river mouth	0	1	1	0.75	**1**
4	VMLcav001	Covignano hill	0.75	0.75	0.75	0.50	**0.75**
5	VMLcav002	Santarcangelo caves	0.75	1	0.50	0.75	**1**
6	VMLflv002	Ponte Verucchio canyon	0	0	0	0.25	**0.25**
7	VMMhum002	San Giovanni in Galilea quarry	0	0.50	0.50	0.50	**0.50**
8	VMMrel001	Verucchio peak	0.75	1	1	1	**1**
9	VMMrel002	Torriana and Montebello peaks	0.25	1	0.50	0.50	**1**
10	VMMrel003	Speco cliff	0	0	0	0.25	**0.25**
11	VMMrel004	Mt. Matto, Mt. del Ronco and Mt. la Costa	0	0	0	0.25	**0.25**
12	VMMrel005	Pietracuta peak	0.75	1	0.75	0	**1**
13	VMMhum003	Mt. Ceti quarry	0	0.75	0	0.50	**0.75**
14	VMMmmv001	Ponte Santa Maria Maddalena boulders	0	0.50	0	0.25	**0.50**
15	VMMrel006	Tausani cliff	0.5	1	0	0.25	**1**
16	VMMrel007	Montemaggio hill	0.75	1	0.25	0	**1**
17	VMMkar001	Legnagnone chalks	0	0.25	0	0	**0.25**
18	VMMrel008	Mt. Pincio, Perticara and Mt. Aquilone	0.75	1	0.75	0.75	**1**
19	VMMmmv002	San Leo cliff	1	1	1	0.25	**1**
20	VMMmmv003	Maiolo cliff and badlands	1	1	1	0.25	**1**
21	VMMmin001	Perticara mines	0	1	0.25	0.25	**1**
22	VMMkar002	Sapigno syncline	0	0	0	0.25	**0.25**
23	VMUmmv004	Mt. Ercole and Mt. San Silvestro	0.75	1	0.75	0.50	**1**
24	VMUrel009	Mt. San Marco peak	0	1	0	0	**1**
25	VMUrel010	Petrella Guidi boulder	0.75	1	0.50	0.25	**1**
26	VMUmmv005	Maciano hill	0.75	1	0.50	0.25	**1**
27	VMUlac001	Scavolino palaeo-lake	0.50	1	0.75	0.25	**1**
28	VMUmmv006	Mt. Carpegna	1	0.75	0.50	1	**1**
29	VMUrel011	Rocca Pratiffi boulder	0.75	1	0.50	0.25	**1**
30	VMUmmv007	Pennabilli mounts	1	1	1	1	**1**
31	VMUstr001	Senatello-Marecchia confluence anticline	0	0	0	0.25	**0.25**
32	VMUstr002	Casteldelci cliff	0	0	0	0	**0**
33	VMUstr003	Mt. Faggiola Vecchia and Mt. Faggiola Nuova	0	1	1	0	**1**
34	VMUtec001	Sant'Alberico's intra-mountain basin	1	1	1	0.25	**1**
35	VMUflv003	Senatello springs	0	0	1	0	**1**
36	MTFstr004	Pietrafagnana mount	0.75	0.25	0.50	0.25	**0.75**
37	MTFstr005	Pietrarubbia mount	0.75	1	1	1	**1**
38	VMUflv004	Tevere springs	0	1	0	0.50	**1**
39	VMUmmv008	Mt. Fumaiolo	0	1	0	0.25	**1**
40	VMUstr006	Molino di Bascio cliff	0.75	1	0.50	0.50	**0.75**
41	VMUcav003	Miratoio peak	0.75	1	0.75	0.75	**0.75**
42	VMUmmv009	Sasso Simone and Simoncello	1	1	1	1	**1**
43	VMUflv005	Marecchia springs	0	1	0	0	**1**

Table 5. Cultural value assessment for Valmarecchia and Montefeltro geosites.

Geosite			Total score	Protection status		
Nr	Code	Name		in place	advisable	not needed
1	VMLmar001	Coastal palaeo-sea cliff	1.92		x	
2	VMLhum001	Rimini town	1.98		x	
3	VMLflv001	Marecchia river mouth	1.84		x	
4	VMLcav001	Covignano hill	2.19		x	
5	VMLcav002	Santarcangelo caves	2.44		x	
6	VMLflv002	Ponte Verucchio canyon	2.44	x		
7	VMMhum002	San Giovanni in Galilea quarry	1.98			x
8	VMMrel001	Verucchio peak	2.94		x	
9	VMMrel002	Torriana and Montebello peaks	3.67	x		
10	VMMrel003	Speco cliff	2.76	x		
11	VMMrel004	Mt. Matto, Mt. del Ronco and Mt. la Costa	2.63	x		
12	VMMrel005	Pietracuta peak	3.05		x	
13	VMMhum003	Mt. Ceti quarry	2.23			x
14	VMMmmv001	Ponte Santa Maria Maddalena boulders	2.11		x	
15	VMMrel006	Tausani cliff	3.78	x		
16	VMMrel007	Montemaggio hill	2.68			x
17	VMMkar001	Legnagnone chalks	2.61	x		
18	VMMrel008	Mt. Pincio, Perticara and Mt. Aquilone	3.84	x		
19	VMMmmv002	San Leo cliff	3.65	x		
20	VMMmmv003	Maiolo cliff and badlands	3.82	x		
21	VMMmin001	Perticara mines	3.36	x		
22	VMMkar002	Sapigno syncline	2.65	x		
23	VMUmmv004	Mt. Ercole and Mt. San Silvestro	3.72	x		
24	VMUrel009	Mt. San Marco peak	3.15		x	
25	VMUrel010	Petrella Guidi boulder	2.94			x
26	VMUmmv005	Maciano hill	3.27	x		
27	VMUlac001	Scavolino palaeo-lake	3.49	x		
28	VMUmmv006	Mt. Carpegna	3.90	x		
29	VMUrel011	Rocca Pratiffi boulder	3.07		x	
30	VMUmmv007	Pennabilli mounts	3.11		x	
31	VMUstr001	Senatello-Marecchia confluence anticline	2.52	x		
32	VMUstr002	Casteldelci cliff	2.27		x	
33	VMUstr003	Mt. Faggiola Vecchia and Mt. Faggiola Nuova	3.00		x	
34	VMUtec001	Sant'Alberico's intra-mountain basin	3.40	x		
35	VMUflv003	Senatello springs	2.67			x
36	MTFstr004	Pietrafagnana mount	3.32	x		
37	MTFstr005	Pietrarubbia mount	3.57	x		
38	VMUflv004	Tevere springs	3.23	x		
39	VMUmmv008	Mt. Fumaiolo	3.94	x		
40	VMUstr006	Molino di Bascio cliff	2.89		x	
41	VMUcav003	Miratoio peak	3.59	x		
42	VMUmmv009	Sasso Simone and Simoncello	3.94	x		
43	VMUflv005	Marecchia springs	2.56		x	

Table 6. Total scores and protection status for Valmarecchia and Montefeltro geosites.

4.3 Description of existing and proposed geosites

The following descriptions of the geosites derive from the information available on Emilia-Romagna dedicated websites, revised in the contents and bibliography and enriched with information obtained thanks to field surveys to enhance both the scientific and additional values and features of the geosites. Contextually, descriptions were added for new proposed geosites identified by this research. Indications have been given about the presence of the sites in the official ISPRA National inventory of geosites.

A brief description was compiled for the existing geosites of the Republic of San Marino, which could, in many cases, be revised as they insist on contiguous land (see *Geomorphological map*).

Finally, a description of the geomorphological points of interest *Valmarecchia rupestrian tubs* has been given.

4.3.1 Valmarecchia and Montefeltro geosites

The geosites in the Marecchia valley have first been listed in the Regional Law D.L. 9/2006 (i.e., Rules for the conservation and enhancement of geodiversity in Emilia-Romagna and related activities), which established the regional geosite register. Nine new proposals for geosites (8 of which can be considered geomorphosites) have been identified, highlighting those processes or places that are still not well known in the context of the Marecchia Valley and Montefeltro historical region.

1. VMLmar001 Coastal palaeo-sea cliff (SN, geomorphosite)

   A vast cliff was located along the coastline of Rimini from Bellaria to Cattolica localities before natural and anthropic influences intervened to erase a good part of it. A residual portion can be found between Viserba and Igea Marina, slightly upstream from the road along the shoreline, with a maximum difference in the height of up to 6-7 m. It identifies the boundary between the alluvial plain of the Marecchia River and the coastal plain's littoral sands and gravel deposits. This gentle escarpment, which extends south-eastwards until it becomes very pronounced between Riccione and Cattolica, where it reaches 10 m in height, bears witness to an ancient shoreline level that stands a few metres higher than the present one. Various authors have assigned different dates to the sea cliff, spanning from the post-glacial Optimum to c. 1000 years BP (Coltorti M., 1991; Elmi et al., 1994; Elmi et al., 2002; Parea G.C., 1986; Severi & Zaghini, 1996; Veggiani A., 1988). Some authors (Coltorti M., 1991; Elmi et al., 1994, 2002) relate the sea cliff to the Roman climate optimum (c- 100-200 AD), but the dating is still unclear. Specific evidence suggests that the scarp has been active (or reactivated) in post-Roman times (Severi & Zaghini, 1996). Marine erosion then caused some important springs (Pantiera, Sacramora and Sortie) to form at the escarpment base, fed by the groundwater stored in the Marecchia alluvium.

Geoscientific interests: geomorphological, hydrogeological;

Geotypes present: escarpment, spring;

Contextual interests: landscape;

Values: scientific, divulgative;

Protection: advisable;

Accessibility: very easy (access for people with motor disabilities).

Registered on the ISPRA National inventory of geosites as *Falesia di Bellaria-Igea Marina* (point feature).

2. VMLant001 Rimini town (URB, geomorphosite)

The town of Rimini is located at the southernmost end of the Po Plain. The municipality comprises the last hillsides of the substantially Pliocene-Pleistocene age, the terraced continental alluvium of the plain (AES8 and AES8a, Pleistocene-Holocene) and the coastal deposits (AES8a, Holocene - present day). The site's geomorphology mainly depends on the Marecchia River and marine processes in

Holocene times. The name itself probably derives from Etruscan *Armne*, which later became the Latin *Ariminus*, which indicates the river, and *Ariminum*, for the settlement born at its mouth. A new name for the river is found in medieval documents of the X century. *Maricula* (i.e., little sea) is the term the word Marecchia comes from and indicates a sea-like appearance of the terminal reach, wide and marshy due to the frequent channel diversions and floods. The dedicated geomorphological map of the area (Guerra et al., 2020) highlights the natural factors that influenced the historical evolution of the town, relating them to anthropic features, with acmes in natural changes matching periods of climate deterioration. The Marecchia River pattern changed, in fact, frequently and drastically during the climate deterioration of the Early Middle Ages, and the toponym San Martino in Riparotta (from Latin *ripa rupta*, i.e., broken river bank or levee) testimonies the main diversion in the most terminal part of the river. It shifted the mouth ca. 2 km north from its supposed Roman position, reaching the present Viserba dock (Veggiani A., 1983) and was repetitively reactivated in historical time (Clementini C., 1617; Tonini L., 1856). This feature has been identified according to shallow gravel deposits (at a depth of less than 10 m) analysis through existing records and LiDAR analysis. The Marecchia River then aggraded and overflowed also during the climate deterioration of the Little Ice Age and until the early twentieth century, causing a critical advancement in the shoreline (more than 1 km in correspondence to the historic harbour). Geomorphological elements related to past landforms and processes hidden under multiple urbanisation stages in Rimini and their enhancement could make Rimini a perfect candidate for the title of Urban Geomorphosite (sensu Reynard et al., 2017). This new reading of the urban fabric in relation to geomorphology could integrate the city's outstanding cultural tourism offer with a naturalistic approach, which can lead to better communication of the stages of the city's evolution, considering the environmental changes that occurred through time.

Geoscientific interests: geomorphological, hydrogeological;

Geotypes present: fluvial branches, spring, marine environment;

Contextual interests: landscape; urban; historical, cultural;

Values: scientific, divulgative, geotouristic;

Protection: advisable;

Accessibility: very easy (access for people with motor disabilities).

3. VMLflv001 Marecchia River mouth (URB, geomorphosite)

This geosite is included in the wider "Rimini town" proposed geosite, as it highlights the former Marecchia River mouth in correspondence to the main historical channel and the artificial riverbed constituting the main watercourse since the 1940s. The Marecchia River runs for its last two kilometres in the deviator canal, an artificial riverbed built to keep the effects of frequent flooding away from the city centre. From Roman times, the river passed under the Tiberius Bridge, and the mouth of the Marecchia River underwent several important shifts

Figure 20. Historical Marecchia River mouth, in correspondance to Tiberius Bridge (I century AD).

over the following centuries, resulting in sometimes disastrous flood events. Today the area is interested in a public park and underwent several interventions to counteract the tendency to return marshy due to the high level of the water table and the occasional return of a consistent river flow during particular weather events.

Geoscientific interests: geomorphological, hydrogeological;

Geotypes present: river mouth, artificial channel deviation;

Contextual interests: historical, cultural;

Value: divulgative, geotouristic;

Protection: advisable;

Accessibility: very easy (access for people with motor disabilities).

4. VMLcav001 Covignano hill (SU)

Covignano is located at the top of a small hill close to the town of Rimini (ca. 2 km from the city centre). The geology of the site presents the evolution of the Pliocene-Pleistocene succession of the Argille Azzurre formation (AAS, Middle Pliocene – Lower Pleistocene), which passes to sands of a more shallow sea with a regressive tendency. The last are representative of the Arenarie e argille di Savignano formation (SVG and SVGa - Grottarossa lithofacies, Lower Pleistocene). At the summit of Covignano hills, the characteristic poorly cemented yellow sands (commonly and improperly called *tufo,* i.e., tuff) belong to the sands of Imola (IMO formation) of the Middle Pleistocene. Gravel levels are interspersed within the yellow sands and are made up of calcareous pebbles from the Marecchia Valley and siliceous pebbles from the Marche coasts. These siliceous pebbles, among which the red ones of the Cretaceous-Eocene Scales of the Marchean Apennines stand out, were transported here through longshore currents (Veggiani, 1988) and are representative of phases of more energetic environments, such as coastlines and delta lobes. The recent evolution of the site comprehends mass movements and human interventions due to the extreme workability of the sandy rocks that brought to a vast number of underground tunnels and caves (closed to the public), which contribute to raising susceptibility to local seismic response effects[14]. The site has been characterised by human presence since as far back as 800,000 years BP (Antoniazzi et al., 1998), during the late Pleistocene, when the hill was already populated, as evidenced by Palaeolithic tools and testimonies found there (Fontemaggi & Piolanti, 1995), making it one of the oldest prehistoric sites in Italy (Peretto C., 1994; Arzarello & Peretto, 2010). Etruscan testimonies can be found on the Covignano hills from the VI century BC. Roman people went to the hill at least for cultic and religious purposes, as attested by a rudimentary sandstone catchment basin discovered during excavations in the 1960s by Galvanina's spring (Ravara Montebelli C., 2020). This water source is one of the geosites of the Valmarecchia and Montefeltro areas that are included in ISPRA's National Inventory of Geosites (ID 1373 *Sorgenti e Terme della Galvanina*). However, it is not included in the Emilia-Romagna list. Another characteristic element of this proposed geosite is the numerous caves that open up in the sands of Covignano hill. The most recent of them are air-raid shelters dug in haste during the front passage in the Second World War. The others have been used as wine and food stores for at least some centuries. The two most significant caves were mentioned in 1848 by the riminese historian Luigi Tonini (Tonini L., 1848). One of them was discovered in 1834 and is made up of five narrow tunnels about a metre wide; the longest is 24 metres long, and at the end of each tunnel, a vertical vent reaches the surface and ensures air change. Its Roman origin seems to be proven by the archaeological finds. The other significant complex is the one traditionally known as *Grotta dei Romiti*, which consists of a descending tunnel that forks after about 10 metres and leads into two chambers. These artificial caves resemble those of Santarcangelo (included in geosite n. 5 Santarcangelo caves) on a smaller scale in their linear

[14] Quadro conoscitivo PSC. Comune di Rimini, Sistema ambientale e naturale. Relazione Geologica (B.REL.GEO - Piano Strutturale Comunale). Approved by Resolution No. 15 of 15/03/2016.

development and carving materials. Recent collaborations between the municipality of Rimini and several private and public entities led to the popularisation of Covignano hill via a dedicated website and Web-GIS applications showing trails[15], natural, historical and cultural features[16] and accommodation facilities[17], the creation of a 6 km long trail by the Rimini section of CAI (Club Alpino Italiano) in 2021 and various dedicated cultural and naturalistic treks.

Geoscientific interests: sedimentological, stratigraphic;

Geotypes present: stratigraphic succession, sedimentary structures, artificial cavity;

Contextual interests: historical, cultural;

Value: divulgative, geotouristic, excursion;

Protection: advisable;

Accessibility: easy.

Registered on the ISPRA National inventory of geosites as *Sorgenti e terme della Galvanina* (point feature).

5. VMLcav002 Santarcangelo caves (SU)

Santarcangelo lies on Colle Giove, a small hill on the left side of the Marecchia River at a short distance from the sea (ca. 7 km). The hill consists of Imola sands (IMO formation), weakly cemented sands that were deposited less than a million years ago along the last beaches that bordered the Apennines during the Pleistocene. An important anthropic cave system, consisting of more than 150 hypogea, has been carved into the sands in past centuries, as already documented by Lotti et al., 1994 and recently 3D mapped (Petruzzi et al., 2021). The first source dates back to 1496, while others become consistent from the 18th century onwards

[15] Sentieri Covignano https://bit.ly/3ms0FLD

[16] Covignano, Spadarolo e Vergiano. Sentieri storici e naturalistici. https://bit.ly/3J4ptDj

[17] Mappa strutture ricettive e sentieri. https://bit.ly/3srwHes

(Bebi & Delucca, 1994). The documents attest to their usage as cellars (as wineries or pantries) from 1700, although a different original function cannot be ruled out if the genesis of these rooms dates back to more distant times (Petruzzi et al., 2021). The anthropic hypogea are interestingly arranged perpendicularly to isohypses, often generating levels of several overlapping rooms. There are three types of hypogea in Santarcangelo based on the cavities' plans: the simple (hall) type, the comb type, and the complex type. The first type consists of single rooms with a rectangular or square plan; the second is characterised by the presence of a gallery, not very large in size, with identical niches on both sides (Pietramellara & Menghi, 1994). Of the complex type are the biggest caves in Santarcangelo: Contradina-Amati, Nadiani-Teodorani, Felici, and Grotte delle Nache. The caves were used as a shelter during the Second World War. The monumental public cave (Contradina-Amati) can be visited accompanied by a tourist guide.

Geoscientific interests: sedimentological, stratigraphic;

Geotypes present: stratigraphic succession, sedimentary structures, artificial cavity;

Contextual interests: historical, architectural, cultural;

Values: scientific, divulgative, geotouristic;

Protection: advisable;

Accessibility: easy.

Registered on the ISPRA National inventory of geosites as *Cavità artificiale di Santarcangelo di Romagna* (point and polygon feature).

6. VMLflv002 Ponte Verucchio canyon (SU, geomorphosite; former *Successione pliocenica lungo il Marecchia*; i.e., Pliocene succession along the Marecchia River)

   Starting from the Ponte Verucchio bridge and for 7 km downstream, the Marecchia River hardly cuts down into the rocks below, forming a deep canyon. This landform has been modelled inside the Argille Azzurre formation (Lower and Middle Pliocene) and has a recent evolution since it was triggered by the intense excavations of inert materials that started in the 50s and reached the maximum exploitations during the 70s. This activity caused the downcutting trend of the river, which in turn exposed the clays and several fossiliferous levels. Vertical layers are found in the first portion, while the angle reduces moving downstream. Also, slumps can be observed on the walls. This succession reaches a thickness of almost 2,000 m, testifying to a high sedimentation rate in the period following the final settlement of the Valmarecchia Nappe. The fossil record counts more than 20 species of Pliocene marine fauna found in the site, including cod and swordfish, sharks, trumpetfish and seahorses; the environment was a deep open sea, assumingly as warm as tropical seas. The "Parco della Cava" site in Poggio Berni (RN) consists of several installations and illustrative signs of educational nature, entirely devoted to the geological and paleontological history of the site. The structures, which are located inside an inactive quarry, enhance the fossiliferous heritage of the nearby pebbly shore, but unfortunately, they lie in almost complete abandonment and have suffered vandalisation.

Geoscientific interests: stratigraphic, palaeontological, geomorphological, structural, applied geology;

Figure 21. Erosional downcutting of the Marecchia River at Ponte Verucchio site.

Geotypes present: ichthyolites, former quarry, sunken riverbed, vertical layers, stratigraphic succession;

Contextual interests: landscape;

Values: scientific, divulgative, geotouristic;

Protection: already in place (ZSC IT4090002 - Torriana, Montebello, Fiume Marecchia);

Accessibility: easy.

7. VMMant002 San Giovanni in Galilea quarry (SU, geomorphosite)

The relief on which San Giovanni in Galilea stands is representative of the classic morphology and geological structure of the Valmarecchia Nappe, of which this ridge represents the northernmost offshoot. It is composed of the San Marino formation calcarenites and orientated WNW-ESE, transversal to the Uso valley axis. Most of what one can observe from the Valmarecchia side is an extensive active quarry cutting the calcarenites. A unique touristic action proposed in the evocative landscape of the quarry has been the *Cene in cava* (i.e., Dining in the

Figure 22. San Giovanni in Galilea mount and active quarry site.

quarry, summer 2021) gastronomic review, consisting of three appointments which meant to enhance the food and wine heritage along the Uso River valley, but also included a guided tour of the quarry area. In the town centre, Renzi Museum has a naturalistic section where several Earth Sciences topics are illustrated, such as the evolution of the Earth and organisms, geological eras and fossilisation processes. The geological collection exhibited includes minerals and rocks from the Uso and Marecchia Rivers area. Also, a fossil collection is preserved, composed of pieces from San Giovanni and the Marecchia River. Lastly, the geomorphological and geological peculiarities of the territory between the Uso and Rubicone rivers are explained.

Geoscientific interests: geomorphological, stratigraphic, applied geology;

Geotypes present: active quarry, ridge, stratigraphic passage;

Contextual interests: archaeological, historical, landscape;

Value: scientific, divulgative, geotouristic;

Protection: not necessary;

Accessibility: easy.

8. VMMrel001 Verucchio peak (SU, geomorphosite)

Characteristic tabular relief made out of calcarenite limestones of San Marino formation (SMN), unconformably lying on the Argille Varicolori formation (AVR). On the North and stratigraphically lays on Argille Azzurre formation (FAA) on the South. It represents the calcareous boulder that moved closer to the seashore. It is a tabular relief where human presence has been almost continuous since ancient times. It is, in fact, a known Villanovian site that thrived during the Early Iron Age (10th-7th centuries BC). Some recently found features, such as canals, ditches and palisades that emerged in the Pian del Monte area during excavations conducted by the University of Pavia, are closely linked to the first phase of the urbanisation process and are dated between the Final Bronze Age and the First

Figure 23. Verucchio village and fortress.

Iron Age when the hilltop settlement became the regional centre of reference (Zamboni & Rondini, 2021).

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: geomorphological, stratigraphic;

Geotypes present: tabular relief, stratigraphic succession;

Contextual interests: historical, cultural;

Values: scientific, divulgative, geotouristic;

Protection: advisable;

Accessibility: very easy (access for people with motor disabilities).

9. VMMrel002 Torriana and Montebello peaks (SN, geomorphosite)

Torriana castle ruins stand on a classic elongated ridge relief, where limestones of San Marino formation and M. Fumaiolo formation lay in unconformity upon Argille Azzurre formation (Borello sandstone member) in a complex setting, representative of the Valmarecchia Nappe. The asymmetry of the ridge reflects

Figure 24. Saiano boulder (in front) and Montebello peak.

the complex imbricate geological structure of the Nappe. Among Montebello and Saiano, one can observe an articulate ridge that ends at Saiano after being interrupted by the Saiano creek and a series of landslides, active or dormant. The Saiano locality, part of the geosite, is particularly interesting for its singular position (i.e., a calcareous boulder emerging at a short distance from the riverbed) and for the historical and religious assets existing in it, such as the circular tower and the monastery, with the presence of the rupestrian evidence known as Madonna's seat (VMMrup001). In the Gesso locality, Messinian gypsum strata can be closely observed. An intense extraction system is still operating nowadays, constituting the only one in Emilia-Romagna extracting selenitic gypsum with aesthetic decorative function. The typical dovetail gemination is recognisable in 3 massive layers of selenite, with soft bituminous clay layers in between them, representative of three evaporitic cycles, the second of which is crossed by a dissolution surface. The upper cycle is the thickest, totalling 15-20 m, truncated at the roof by a very pronounced dissolution surface.

Figure 25. Torriana charachteristic peaks.

Natural cavities are included in the area or in the proximities of the geosite (RN 474 Grotta delle farfalle, RN 472 Grotta di Saiano).

Geoscientific interests: geomorphological, stratigraphic, sedimentological structural, mineralogical;

Geotypes present: overlap, gullies, ridge, cliff, selenitic chalk, stratigraphic succession, sedimentary structures;

Contextual interests: historical, architectural, landscape;

Values: scientific, divulgative, excursion, geotouristic;

Protection: already in place (ZSC IT4090002 - Torriana, Montebello, Marecchia River);

Accessibility: easy.

Registered on the ISPRA National inventory of geosites as *Rupi di Torriana e Montebello* (point and polygon feature).

10. VMMrel003 Speco cliff (NAT, geomorphosite)

Rock cliff along the left side of the Marecchia valley that extends until the Uso Creek watershed. It is composed of massive arenaceous or conglomerate layers of the Argille Azzurre formation (Borello Sandstone member) lying upon Acquaviva formation (AQV). The site is representative of the intrappenninic Pliocene succession along the Marecchia valley. There is a wall of lesser height in the area above, where the same lithologies outcrop.

Geoscientific interests: geomorphological, stratigraphic;

Geotypes present: stratigraphic passage, stratigraphic succession, cliff;

Contextual interests: landscape;

Values: scientific, divulgative;

Protection: already in place (ZSC IT4090002 - Torriana, Montebello, Marecchia River;

Accessibility: easy.

Figure 26. Speco cliff, the Marecchia river and Pietracuta alluvial plains (in front).

11. VMMrel004 Mt. Matto, Mt. Del Ronco and Mt. La Costa (SN, geomorphosite)

The three small reliefs of Mt. Matto, Mt. del Ronco and Mt. la Costa are representative of the geological and geomorphological structure of the Coltre della Valmarecchia. They are formed by Monte Fumaiolo formation and Pliocene sandstones and conglomerates of the Argille Azzurre formation (Borello member), in morphological prominence along the left side of the Marecchia River. These lithotypes are in stratigraphic sequence upon the Ligurian Units, represented by the Varicoloured Clays of the Valsamoggia, outcropping in the underlying gully basins. The primary stratigraphic contact between Ligurian and overlying soils appears to be laminated by tectonics, especially on the slopes of Monte la Costa.

Geoscientific interests: geomorphological, structural, stratigraphic;

Geotypes present: fault, gullies, stratigraphic passage, pyramidal relief;

Contextual interests: landscape;

Values: scientific, divulgative, geotouristic;

Protection: already in place (ZSC IT4090002 - Torriana, Montebello, Marecchia River);

Accessibility: easy.

12. VMMrel005 Pietracuta peak (SN, geomorphosite)

The ancient Pietracuta settlement stands on the top of a pyramidal shape relief that can be distinguished from afar, formed by sandstones of the Acquaviva formation (Tortonian), which rises from the bottom of the Marecchia valley in stratigraphic discordance on the underlying San Marino formation. The base of this succession rests on the Argille Varicolori della Valmarecchia formation. This cliff is a significant example of the Marecchia valley landscape. The contrasts of erodibility between the clayey Ligurian units and the more competent epiligurian units above give rise to isolated reliefs bordered by sub-vertical slopes. These cliffs rise with considerable energy on the surrounding slopes, presenting weak

Figure 27. Pietracuta peak and castle ruins.

acclivity, gullies and landslides. The Acquaviva formation consists mainly of coarse sandstones, with scattered pebbles, in irregular layers, generally massive and thick and in banks, laterally discontinuous. Subordinate are the conglomerate levels generally lenticular, where they assume a relevant power, as at the base of the formation, they have been mapped as the conglomerate lithofacies. Sandstones are yellowish-grey, sometimes with sedimentary structures, such as cross-laminated, plane-parallel lamination, and fluid leakage structures. They are also generally rather bioturbated and have abundant fossil remains, both in the form of fragments scattered in the sandstones or as levels consisting exclusively of shell fragments of molluscs (Ricci Lucchi, 1964). Carbon whips are also widespread, more frequently in the basal part of the formation in which lignite deposits have been exploited in the past (Ruggieri, 1954). The sedimentary structures recognised in the formation indicate the proximal marine environment, particularly delta-marine apparatuses (Conti, 1990). On the top of the cliff, on the edge of the rocky outcrop (known in ancient times as Pietra Aguzza or

Pietraguidola), stood the Castle of Pietracuta, dating back to the tenth century, of which some architectural evidence and the ruins of the fortification remain. The function of this fortification was to sight the entire stretch of the lower Marecchia valley. The castle was destroyed in later centuries and has suffered from abandonment; in the 1950s, part of the cliff was collapsed. The cliff's stability was further aggravated by quarry activities on the eastern hillside, whose signs are still observable even if partially covered by vegetation. On this day, access to the few remnants of the fortress is prohibitive, and there are not any proper trails that lead to the top of the peak. On the other hand, access to the western portion of the geosite (Case Monte) is really easy and represents one of the classified paleosurfaces (S5).

Geoscientific interests: geomorphological, stratigraphic;

Geotypes present: stratigraphic passage, pyramidal relief;

Contextual interests: historical, landscape;

Value: divulgative, excursion, geotouristic;

Protection: advisable;

Accessibility: easy.

13. VMMant003 Mt. Ceti quarry (SU)

Mt. Ceti is a relief that stands out along the valley floor to the left of the Marecchia River, consisting of calcarenites of the San Marino formation and the sandstones of Monte Fumaiolo formation, marked by a large quarry area. The light-coloured quarry vertical surface is a distinctive trait in the middle sector of the valley and enhances the difference in the landscape that mining activity can make. Comparing the site with aerial pictures of the past, one can clearly see the advancement of the mining industry, and thus the flattening of the previously existing sharp relief, which is nowadays limited to a single peak. In the mining area, at the contact between the clays referred to the Ligurian units (Argille Varicolori della Valmarecchia) and San Marino formation, an extraordinary

Figure 28. Monte Ceti quarry site.

fossilised sea reptile skull of Cretaceous age (90-65 million years ago) was found in September 2010, which has been attributed to a mosasaur. The rest of the fossil, having dimensions of about 60 x 30 cm, is very well preserved and provides many clues for its correct identification. Due to the anatomical features and the rarity in the typology, the specimen has a significant scientific value for the paleo-zoological and paleoenvironmental information that can be obtained from it. The outcrops enhance, in fact, two distinct intervals. The lower part of the deposits consists of alternating dark-coloured deep-sea clay deposits and turbiditic levels, and the mosasaur was found in this stratigraphic interval. The overlying layers consist of light-coloured clay deposits interspersed with limestone layers a few centimetres thick. The fossil is preserved at the G. Capellini University Geological Museum of Bologna. The site is known to geologists and mineralogists for the richness of septaria, natural concretions that include chalk crystals, calcite, aragonite and barite. In the clays are also common isolated gypsum crystals and nodules of pyrite-marcasite. A hilltop settlement stood at the top of Mt. Ceti, as testified by the finding of a burial site and some ceramic material, attesting to a population since the Early Bronze Age.

Geoscientific interests: palaeontological;

Geotypes present: marine vertebrates;

Contextual interests: landscape;

Value: scientific, divulgative;

Protection: not necessary;

Accessibility: easy.

14. VMMmmv001 Ponte Santa Maria Maddalena boulders (SN, geomorphosite)

Slightly downstream from the bridge crossing the Marecchia River in correspondence to the Ponte Santa Maria Maddalena village, there is a spectacular stretch of river, extremely unusual for this part of the valley. In this sector, massive boulders have been transported to the riverbed that runs depositing and cutting sediments among them. The site is located at the intersection between the Marecchia riverbed and an arcuate slab that dislocates Epiligurian deposits upon Ligurian units and runs orthogonally to one of the main movement directions of the Valmarecchia Nappe. Mt. Ceti on the left side and Mt. Fotogno on the right side of the valley tower over the site and are the most suitable origin for the boulders that can be found inside the riverbed. In all probability, this has been a crossing site since ancient times, as at least a river ford (Rodriguez E., 2001).

Geoscientific interests: geomorphological;

Geotypes present: boulders, mass movements;

Contextual interests: historical, landscape;

Value: divulgative, excursion, geotouristic;

Protection: advisable;

Accessibility: easy.

15. VMMrel006 Tausani cliff (SN, geomorphosite)

A massive ridge extends from the right bank of the Marecchia River to the San Leo cliff, through the peaks of Mt. Fotogno, Mt. Gregorio, Mt. Tausano and Mt. San Severino. This spectacular ridge represents the Valmarecchia landscape, where erosive contrast within Argille Varicolori clays and limestones originates isolated reliefs, with vertical slopes and surrounding badlands. San Marino, Mt. Fumaiolo and Acquaviva formations outcrop; the transition from San Marino to Mt. Fumaiolo formation represents the ending of sedimentary carbonate contribution and an increase in terrigenous intake. The Tausani ridge path is one of the most impressive trails in the study area and offers a spectacular view of both the Mazzocco and the Marecchia River valleys. The geosite comprehends three rupestrian tubs, even if at least another has been recently discovered and not yet investigated. The mapped rupestrian tubs are Masso del Tino tubs (VMMrup005), on the trail leading to the top of Mt. Fotogno, Mt. Fotogno tub (VMMrup006) and Tausano tub (VMMrup007). Masso del Tino (meaning Vat boulder) is fascinating evidence because two separate tubs have been carved in

Figure 29. Tausani cliff, with Penna del Gesso on the left and Tausano rock-fall on the right.

the same boulder. One of them is standing vertically, suggesting that the block involved a rock-fall that transported it from its previous location to the current one. Subsequentially to the rock-fall, another tub has been carved on the top of the same boulder. Another tub has been recently found at the top of Mt. Fotogno (January 2020), which lies broken in half, most likely fallen from the cliff. The Tausano tub is located on the ridge path, with a rectangular shape. A geomorphological point of interest related to this geosite is the Tausano landslide, a significant mass movement that occurred in 1822 and reactivated multiple times in the following two centuries. This complex mechanism includes rock-falls, topplings and mudflows, that endangered Tausano and other villages, modifying the morphology at different times, as evidenced by local historical records (Guerra & Nesci, 2013). Access to the site is easy.

Geoscientific interests: geomorphological, stratigraphic, sedimentological;

Geotypes present: landslide, cliff, buttress, stratigraphic succession, sedimentary structures;

Contextual interests: architectural, landscape, botanical, fauna;

Figure 30. Penna del Gesso site.

Values: scientific, divulgative, excursion, geotouristic;

Protection: partially already in place (SIC/ZPS IT4090003 - Rupi e Gessi della Valmarecchia);

Accessibility: easy.

16. VMMrel007 Montemaggio hill (SN, geomorphosite)

Montemaggio relief is characterised by two recognisable peaks at the top of the secondary ridge between the Mazzocco and San Marino streams. San Marino formation calcarenites form it, upon clays of the Argille Varicolori della Valmarecchia formation. As for other isolated slabs of the San Marino formation, the Montemaggio one shows intense fracturing and is affected by lateral spreading processes, which occurs in relation to the clayey nature of the materials underlying the relief and brings to deep-seated gravitational slope deformation (DGSD) phenomena. At the foot of the relief, we find the Acquaviva spring, which originates from lithological contact between the fractured limestones of the San Marino formation and the Argille Varicolori, the latter representing the

Figure 31. Montemaggio hill.

impermeable support of the aquifer. The Montemaggio Castle (castrum Montis Madii) remnants are identified on the top of the hill but have suffered from abandonment. Access to the area of the geosite is very easy.

Geoscientific interests: geomorphological, stratigraphic, hydrogeological;

Geotypes present: deep gravitational slope deformations, source, pyramidal relief, stratigraphic succession;

Contextual interests: architectural, landscape;

Protection: not necessary;

Accessibility: easy.

17. VMMkar001 Legnagnone chalks and badlands (NAT, geomorphosite)

Around Legnagnone locality, pseudokarst features (caves, sinkholes, karren, microkarren) characterise the Messinian Epiligurian evaporites of the Gessoso-Solfifera formation, which reaches a thickness of about 30 m. Badlands can also be observed in the clays of Casa I Gessi formation. The stratigraphic passage between this unit and the Gessoso-Solfifera formation is clearly visible at the bottom of the thick bank alabaster chalk in morphological prominence along the upper edge of the badlands. The chalk bank is made up of whitish-coloured microcrystalline gypsum, several metres thick, with dark grey pelitic intercalations, and thick banks of selenitic microcrystalline grey-coloured macro-crystalline gypsum, also with dark grey bituminous decimetric levels. Rio Strazzano, a small right tributary of the Marecchia River, is marked by peculiar karst morphologies, including several hypogea-epigean passages of the watercourse, in a picture of rapid evolution due to the succession of collapses. The accessibility to the site is challenging, and particular attention should be given due to the presence of pseudokarstic features.

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: stratigraphic, epigean karst, hypogean karst, geomorphological;

Geotypes present: gullies, waterfalls, natural cavities, sinkholes, canyons, cliff, stratigraphic passage;

Contextual interests: landscape, botanical, fauna;

Values: scientific, divulgative, speleological;

Protection: partially already in place (SIC/ZPS IT4090003 - Rupi e Gessi della Valmarecchia);

Accessibility: difficult.

18. VMMrel008 Mt. Pincio, Perticara and Mt. Aquilone (SN, geomorphosite)

    Perticara rises along the ridge between Marecchia and Savio Rivers, between the Pliocene sandstone outcrops that form the massif of Mt. Aquilone, Mt. della Perticara and Mt. Pincio and a succession of mainly clayey, Miocene sediments that outcrop along the valley of the Fanante stream, in the direction of Savio River. Close to the village of Perticara, the ridge between Marecchia and Savio is marked by the imposing ridge articulated in the reliefs of Monte Perticara, Monte Aquilone and Monte Pincio. From the geological point of view, this is a significant area, a reference point for observing Mt. Perticara arenaceous-conglomerate lithofacies of the Pliocene Argille Azzurre formation. Medium-growth sandstones characterise it in thick layers and intercalations of polygenic conglomerates, whose elements derive from the erosion of Ligurian rocks. Besides the coarse grain size, the distinctive character of these lithofacies is the presence of herringbone stratification. Other types of sedimentary structures found are oblique and cross lamination. Where sandstone predominates, the stratification is clear and well recognisable. These sedimentological features indicate a low sea sedimentation environment influenced by wave motion. The seabed on which sands and pebbles sedimented was located close to the shoreline, shallow and beaten by the wave motion. Along the beaches, the mouths of the rivers ploughed the rivers valleys behind, and the reliefs of an Apennine just emerged from the sea. From the rocks of the Ligurian blanket that surfaced, there came the pebbles of the conglomerates; their presence also testifies the strength with which the river waters reached the mouth. At the foot of Mount Perticara, the sandstones are in tectonic contact with the Ligurian blanket of sandstone, and the sandy bodies immerse towards the blanket of sandstone. In the area above the village of Perticara stands a wall along which the sandstones emerge crossed by a thick mesh of fractures. We owe it the detachment of rocky blocks of various dimensions, with the mobilisation of collapse landslides, also known historically. The important mining sulphur extraction industry is a geological value that lies hidden under the soils of this area and constitutes a geosite by itself (VMMmin001 Perticara mines).

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: stratigraphic, geomorphological;

Geotypes present: ridge, stratigraphic succession, reference area;

Contextual interests: landscape, botanical;

Values: scientific, divulgative, excursion, geotouristic;

Figure 32. Mt. Pincio and Mt. Aquilone.

Protection: already in place (ZSC/ZPS IT4090003 - Rupi e Gessi della Valmarecchia);

Accessibility: easy.

19. VMMmmv002 San Leo cliff (SU, geomorphosite)

Spectacular cliff on the right side of Marecchia River, formed by calcareous limestones of San Marino formation and Monte Fumaiolo formation, lying in unconformity with the Argille Varicolori formation. At the top of the hill, San Leo hamlet and Fortress. The cliffs' vast summit is surrounded by vertical rock cliffs, gentle clay hills, badlands and massive mass movements. The whole mount is hardly fractured, and the intersection between fracture systems and layered banks' surfaces produces topplings and rock-falls, thus endangering the site and the cultural heritage of the hamlet (Benedetti et al., 2011). General instability is due to weathering at the foot of the cliffs, where the Argille Varicolori clays are hardly weathered and progressively leave portions of hanging blocks that fall due to gravity. Related to this geosite is San Leo's rock-fall geomorphological point of

Figure 33. San Leo village and 2014 rock-fall site (on the left)

interest: the northeastern edge of the cliff became popular when the most impressive recent events occurred in 2006 and 2014. These events deposited and displaced, respectively, 50,000 and 300,000 m^3 of rock. Visitors may better understand the volumes of the phenomena after comparing the present-day view of the site and historical testimonies (i.e., Mingucci's 1626 water paint, already published in Benedetti et al., 2011), where significant modification of the cliff profile can be observed. The hamlet faces a high hydrogeological risk, and various studies and interventions have been made to counteract those tendencies. One of the most significant and iconic rupestrian tubs in Valmarecchia is located in the village, enclosed in-between San Leo's church and the bell tower and cut in the sandstones (VMMrup004 San Leo tub). Access to the site is easy.

Geoscientific interests: geomorphological, stratigraphic, sedimentological;

Geotypes present: collapse landslide, cliff, stratigraphic succession, sedimentary structures;

Contextual interests: historical, architectural, landscape;

Values: scientific, divulgative, geotouristic;

Protection: already in place (ZSC/ZPS IT4090003 - Rupi e Gessi della Valmarecchia);

Accessibility: easy.

Registered on the ISPRA National inventory of geosites as *Rupe San Leo* (point feature).

20. VMMmmv003 Maiolo cliff and badlands (SN, geomorphosite)

Maiolo Fortress stands out on the top of an outlier boarded by impressive landslides and colourful badlands, cut within the Argille Varicolori formation. Maiolo block consists of coarse sandstones and conglomerate layers of the Argille Azzurre formation and Monte Perticara lithofacies, representing coastal sedimentary and marginal marine or tidal environments as testified by sedimentary structures, such as herringbone, oblique, and cross lamination.

Argille Varicolori formation outcrops in the eastern badlands with typical chaotic asset and intense deformation. At the base of the southern and eastern outcrops of the cliff, the contact with the clays is evident and can be interpreted as a laminated tectonic contact that testifies to the translation of Pliocene soils onto those of the Valmarecchia Nappe. Due to intense fracturing, numerous blocks fell from both sides of the cliff and were deposited at the foot of the slopes, moving towards the watersheds floating on mudslides that involve the clays. At least two significant landslide events can be enhanced in Maiolo, which constitute geomorphological points of interest. One of them is a historical event dated back to 29 May 1700, when a massive portion of sediments yielded from the top of the hill, most probably with a rock-slide movement type (Nesci et al., 2005), causing around 30 fatalities and causing the abandonment of the village (Piastra et al., 2005). The orientation of rock layers in the slope direction was probably a significant control factor in determining the movement. Recent studies have proposed a connection between the landscapes of Piero della Francesca's Doppio ritratto dei duchi di Urbino and the Marecchia valley, with particular reference to

Figure 34. Maiolo cliff and badlands.

the Maiolo cliff, that has been depicted before the massive event that would have destroyed the Hamlet (Borchia & Nesci, 2012; 2021). Mingucci's 1626 water paint (already published in Guerra & Nesci, 2013) gives a faithful view of the village and can be compared to present-day pictures to understand the severity of the phenomenon. Another landslide worth enhancing is located on the eastern side of the cliff, where recent active rock-falls and debris-flows can be observed in their state of activity. Accessibility to the site is easy. A rupestrian tub called *Letto di San Paolo* (i.e., San Paolo's bed, VMMrup008) is located in the proximity of the geosites (locality Piani di San Paolo, on private land).

Geoscientific interests: geomorphological, stratigraphic, structural;

Geotypes present: fault, gullies, collapse landslide, cliff, stratigraphic succession;

Contextual interests: historical, landscape, botanical, fauna;

Value: scientific, educational, excursion, geotouristic;

Protection: already in place (ZSC/ZPS IT4090003 - Rupi e Gessi della Valmarecchia);

Accessibility: easy.

21. VMMmin001 Perticara mines (SU)

Perticara village is located along the ridge between Marecchia and Savio Rivers, between the Pliocene sandstone outcrops that form the massif of Monte Aquilone, Monte Perticata and Monte Pincio and a succession of mainly clayey, Miocene sediments that develop along the valley of the Fanante stream, in the direction of Savio. Although in the vicinity of Perticara it is the imposing sandstone reliefs that dominate the landscape scene, the geological interest of the area focuses on the succession of strata that form the slopes downstream of the village. At the same time, the underground contains the galleries of a massive sulphur mine. In fact, peculiar levels of resedimented gypsum can be found among the Miocene clay strata. The rock is formed by gypsum fragments of various sizes, whose origin is linked to the erosion of pre-existing layers of selenitic gypsum, which has been exposed to erosive agents. Associated with this clastic gypsum are the significant sulphur deposits of Perticara. The presence of this ore has been known since historical times (Veggiani A., 1955) and it has been mined since the 17th century. The most crucial mining phases began in 1917, with the discovery of a strong sulphur seam, and ended in 1964 with the definitive closure of the mining sites and related activities. The tunnels went down to a depth of -740 m on nine cultivation levels, with a linear development of over 100 kilometres, giving the mine the title of the biggest in Europe. Sulphur was extracted by fusion inside cauldrons, underground furnaces where the rock was heated until the sulphur melted, then in more efficient furnaces. The release of waste materials determined morphological reliefs up to tens of metres high or blankets of widespread cover on the slopes in the vicinity of the mining areas. In 1970, six years after the end of mining activity, Sulphur Historical and Mining Museum was opened. In a setting of industrial archaeology, it preserves the most important evidence of mining activity, a large collection of rocks and minerals, several explanatory panels about geology, mineralogy and the mining industry and organises numerous educational and informative activities. To Perticara mines, we also owe the discovery of the world's biggest sulphur crystal, now preserved in the Museum of Natural History in Milan (22.5 x 16.5 x 11 cm, ca. 5 kg in weight). Perticara mines are part of the Marche Sulphur Mining Geopark, established as a national park in 2005 with the function of conserving, restoring and promoting this unique asset of national interest.

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: geominerary, geohistorical, stratigraphic;

Geotypes present: mine, sulphur;

Contextual interests: historical;

Values: scientific, divulgative, geotouristic;

Protection: partially already in place (ZSC/SIC IT4090004 - Monte S. Silvestro, Monte Ercole e Gessi di Sapigno, Maiano e Ugrigno);

Accessibility: easy.

22. VMMkar002 Sapigno syncline (NAT, geomorphosite)

A vast area of stratigraphic interest extends on the Savio River's right side, between the Fanante and Fanantello creeks valleys, where a succession of post-evaporitic Messinian soils contains important volumes of resedimented evaporites outcrops. These latter stand out along the outcrops of the Fanante valley and are recognisable thanks to their light colour and lenticular shape. These soils are visibly deformed into a mild syncline. Their thickness has led to the hypothesis of a sedimentation basin, delimited by faults and more depressed than the surrounding areas. The structural form is reflected in the morphology, where the slopes are arranged according to the layering of the structural surfaces. The perimeter outcrops form steep, modelled cliffs, where the stratification is set in a ridge-like pattern. There are several natural cavities and chalk morphologies of great interest in the area, brought to the surface by the erosion of Fanantello creek. The outcropping succession is known as the Sapigno formation (Roveri et al., 2005), and it is composed of the resedimented, basinal terms of the Gessoso-Solfifera formation. The formation consists of laminated grey and dark grey marly-siltstone clays in medium or fine layers, more rarely thick, with fine arenaceous intercalations.

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interest: stratigraphic, sedimentological, structural, geomorphological, hypogeous karst, epigean karst;

Geotypes present: syncline, natural cavity, cliff, stratigraphic succession, sedimentary structures;

Contextual interests: landscape;

Value: scientific, divulgative, speleological;

Protection: partially already in place (ZSC/SIC IT4090004 - Monte S. Silvestro, Monte Ercole e Gessi di Sapigno, Maiano e Ugrigno);

Accessibility: easy.

23. VMUmmv004 Mt. Ercole and Mt. San Silvestro (NAT, geomorphosite)

Mt. San Silvestro and Mt. Ercole rise along the watershed between the Marecchia and Savio Rivers. The two mounts, mostly wooded, consist of coarse greenish-grey sandstone, in medium to thick layers, with a varied composition: quartz granules and pebbles can be found, as well as feldspar, mica and minerals of volcanic origin. These sandstones alternate with marls and yellowish clay, and silty layers. The sandstones often have a high mica and minerals of volcanic origin content; microconglomerates with quartz pebbles, micaschists, phyllites and calcarenites are interspersed at various levels. The sedimentation of these layers took place on rather deep seabeds between the middle and upper Eocene due to the arrival of turbid current. The sandstones belong to the Monte Comero formation (Middle Eocene p.p. - Upper Eocene p.p) and rest directly on the Argille Varicolori formation, assuming a stratigraphic and structural position typical of the epiligurian formations. The slopes of the two mountains are marked

Figure 35. Mt. San Silvestro and Mt. Ercole.

by morphologies typically linked to the development of deep landslides, such as counter-slopes and “split crests” at different heights. The slope descending towards the Savio is affected by complex landslide movements involving the predominantly clayey soils dating back to the Miocene. For this sector, there are records of impressive landslides which, from 1555 until 1934, affected the area of the village of Sant’Agata Feltria numerous times, developing into two main branches, one of which is still active. This feature represents one of the most interesting aspects of the geosite, especially considering the permanence of the population in the village, despite the constant hydrogeological threat. The most extensive landslide movement took place in 1561 and was reactivated with similar volumes in 1934. The latter originated from the sides of Mt. Ercole, moved towards the village, swept through it and ended after more than 5 km of development. It has been related to particular weather conditions in the area, with summer droughts and heavy rainfall in the months preceding the event (Persi et al., 1993). A geomorphological point of interest can be found in the locality *Piani di San Francesco*, at a 2 km distance from Sant’Agata Feltria village, where a monastery was built following the Saint’s passage in the XIII century (Flenghi & Flenghi, 2019). The structure was of fundamental importance in the social life of the village, as it housed the gymnasium and a music school. Its decay was first caused by the deterioration of its foundations under the action of surface water, incremented during the Little Ice Age, which probably led to soliflux phenomena. After decades of suffering, its abandonment was caused by the damage caused by the 1791 Cagli earthquake, which affected the village with a seismic intensity of grade 7. Nowadays, just a few building stones remain on the site. The area where the ruins of the monastery are located is part of a landscape where landslide phenomena can be observed at different scales, constituting a link between the geological, historical, cultural and religious heritages. Two rupestrian evidences are located in the area of the geosite: Ville di Monte Benedetto tub (VMUrup012) and San Silvestro’s tub (VMUrup013).

Geoscientific interests: geomorphological;

Geotypes present: gullies, deep gravitational slope deformations, pyramidal relief;

Contextual interests: architectural, botanical, religious;

Values: scientific, geotouristic, excursion;

Protection: already in place (ZSC/SIC IT4090004 - Monte S. Silvestro, Monte Ercole e Gessi di Sapigno, Maiano e Ugrigno);

Accessibility: easy.

24. VMUrel009 Mt. San Marco peak (SU, geomorphosite)

Pyramid-shaped relief that consists of limestones of San Marino formation, laying on the Argille Varicolori formation. The mountain stands out in the landscape with a distinct shape. Recent studies have identified Mt. San Marco in Piero della Francesca's Baptism of Jesus (Nesci O., 2012; Borchia & Nesci, 2021). Rocky formations of Mt. San Marco represent the typical Epiligurian plates of the Marecchia Valley; along the slopes, grey organogenic limestone and greyish-white limestone rich in bioclasts are well exposed, and it is easy to grasp their main characteristics: the fracturing, the colour varying from light grey to orange-

Figure 36. Mt. San Marco.

yellow, the coarse grain size, the prevalence of fossil fragments compared to granules of other nature, and the numerous fossil remains, clearly visible. The marly lithofacies of the Argille Varicolori emerges along the western slope of Mt. San Marco, consisting of light brownish-grey marls with rare whitish-grey marly limestones in decimetric layers. The relief has endured massive stone quarrying in historical times, and the previous extent of the mountain is noticeable in historical aerial photos and satellite images. On the top of Mt. San Marco stood the ancient Monte Acuto castle (Sacco D., 2004), whose remnants may be found in a few building stones. San Marco's tub (VMMrup009), one of the most iconic rupestrian tubs of the Marecchia valley, is located at the top of the mount, and it has luckily survived the quarry activities. Accessibility to the site is slightly tricky; the trail that leads to the top is narrow and in traits quite exposed to a steep wooded slope.

Geoscientific interests: geomorphological;

Geotypes present: pyramidal relief, quarry;

Contextual interests: landscape, historical, cultural;

Values: divulgative, geotouristic;

Protection: advisable;

Accessibility: medium difficulty.

Registered on the ISPRA National inventory of geosites as *Rilievi di Monte San Marco* (point feature).

25. VMUrel010 Petrella Guidi boulder (SN, geomorphosite)

The village of Petrella Guidi rises on an isolated limestone rock on the southern slope of the Mt. Ercole and Mt. San Silvestro reliefs. On this site, the built-up area maintains a distinctly medieval appearance and is one of the best-preserved fortified villages in the entire Marecchia Valley, presenting an extension similar to that of the period of castellation. The boulder consists of limestone from the San Marino formation, resting on an olistolite from the Argille Varicolori formation,

Figure 37. Petrella Guidi village.

immersed in the Ghioli di Letto formation. It represents a characteristic example of the migrating character of limestone boulders resting on clays, surrounded by semi-flat surfaces that can be assimilated to pediments, originated by freezing and thawing cycles. In fact, the load of water that can be stored in the clays meant that they were able to transport rock blocks of considerable size over significant distances, during the last glaciation, with a behaviour very similar to that of glaciers. On the top of the settlement, an installation from the artist Tonino Guerra, dedicated to Federico Fellini, can be admired. Also, an illustrative panel about the landscape included in Piero della Francesca's painting "Battesimo di Cristo" explains peculiar geomorphological traits of this portion of the valley (Borchia & Nesci, 2021).

Geoscientific interests: geomorphological;

Geotypes present: boulder;

Contextual interests: landscape, historical, cultural;

Values: geotouristic;

Protection: not necessary;

Accessibility: easy.

26. VMUmmv005 Maciano hill (SN, geomorphosite)

Maciano village is a fraction of Pennabilli municipality and is located down the north-western slope of Mt. Carpegna. The village is settled on a rotational slide that produced several counter-slopes, probably triggered by the DGSD of Monte Morello formation that interest most of Mt. Carpegna. The most ancient settlement, known as Castello del Sorbo (Sorbus Castle), could have been destroyed by cause of a new or reactivated landslide and could be located at the top of the hill that towers over Maciano village (Piana del Cannone, i.e., Cannon plain). The same event could also be a cause for the formation of a lake, known today as Lago di Soanne (Soanne Lake) or Lago di Andreuccio (Andreuccio's Lake), this latter toponym referring to a dramatic legend about a noblewoman and a shepherd secretly in love, according to which the young man was killed by her relatives. The woman decided then to take her own life by immersing herself

Figure 38. Maciano hill and Castello site (on the right).

in the waters of the lake. After the destruction of the castle, a new settlement was established slightly lower in height at today's "Castello" locality.

Geoscientific interests: geomorphological;

Geotypes present: landslide, DGSD;

Contextual interests: historical, cultural;

Values: geotouristic;

Protection: partially already in place (EUAP0969 - Parco Interregionale Sasso Simone e Simoncello, protection area C and partially in the contiguous area);

Accessibility: easy.

27. VMUlac001 Scavolino palaeo-lake (SU, geomorphosite)

In Scavolino village (municipality of Pennabilli), testimonies of an ancient lake can be dated back to historical times but could possibly be extended towards more ancient times based on geomorphological considerations. The village is located on the north-western slope of Mt. Carpegna, where massive landslides characterise the geological landscape. The slope has a differentiated morphological structure due to geomorphological and tectonic features and is characterised by steep slopes in the upper part, with slopes that decrease towards the valley until reaching a sub-flat structure further downstream and a concave morphology near the village. The morphotectonic elements can be traced back to a vast area of deep gravitational deformation of the slope and involve the downward displacement of vast portions of the slope under the action of gravity, which appear currently stabilised. Some core drillings have revealed the presence of lacustrine deposits, which probably originated in a basin of a landslide deposit (Cesarini R., 2013). A particular feature of this palaeo-lake is the drainage work carried out by Count Tommaso di Carpegna between the 15th and 16th centuries, which have transformed it into a fertile horticultural area, still in use today by the inhabitants of Scavolino.

Geoscientific interests: geomorphological;

Figure 39. Scavolino village and paleo-lake site.

Geotypes present: landslide, DGSD, palaeo-lake;

Contextual interests: historical, cultural;

Values: geotouristic;

Protection: already in place (partially in EUAP0969 - Parco Interregionale Sasso Simone e Simoncello, contiguous area; partially in ZSC/ZPS IT4090006 - Versanti occidentali e settentrionali del Monte Carpegna, Torrente Messa, Poggio di Miratoio);

Accessibility: easy.

28. VMUmmv006 Mt. Carpegna (SN, geomorphosite)

Mt. Carpegna is a massive relief standing on the right side of Marecchia valley, connecting it to the Conca valley, which reaches 1,415 m asl. It constitutes of a limestone-marl flysch succession (Monte Morello formation, Eocene inf. - med.) with impressive outcrops mainly on the west side of the relief. The Monte Morello formation consists of an alternation of marly limestones, whose base is often marked by a thickness of turbiditic calcarenites and hemipelagic marls. The northwest side of Mt. Carpegna is characterised by the presence of peculiar morphologies, such as counter-slopes, trenches and topographic irregularities that testify DGSD (deep-seated gravitational slope deformation) on the top of the relief. Landslides are mainly rock-block slides, with a gradual detachment of blocks along rock discontinuities (layer surfaces or softer strata). For the impressive amount and variety of mass movements, the site could be considered a landslide atlas with particular attendance to geotourism (Pieruccini & Coltorti, 2010). Considering the site's geomorphological evolution, the anthropic impact could represent one of the leading agents working with climate change since the land was deforested for agriculture use as early as in the XV century.

Geoscientific interests: geomorphological, stratigraphic, structural;

Geotypes present: fault, DGSD, stratigraphic succession;

Contextual interests: landscape, botanical, fauna;

Values: scientific, divulgative, excursion, geotouristic;

Figure 40. Mt. Carpegna.

Protection: already in place (EUAP0969 - Parco Interregionale Sasso Simone e Simoncello; ZSC/ZPS IT4090006 - Versanti occidentali e settentrionali del Monte Carpegna, Torrente Messa, Poggio di Miratoio; ZPS IT5310026 - Monte Carpegna e Sasso Simone e Simoncello);
Accessibility: easy.
Registered on the ISPRA National inventory of geosites as *Costa dei Salti Monte Carpegna* (point feature).

29. VMUrel011 Rocca Pratiffi boulder (SN, geomorphosite)
The village of Rocca Pratiffi stands at the top of an isolated limestone rock located in the proximities of Petrella Guidi and has an assimilable origin. Few remains of an ancient castle can be observed on the site, standing on a rock block consisting of limestone from the San Marino formation, resting on an olistolite from the Argille Varicolori formation, inside the Ghioli di Letto formation. It represents another characteristic example of the migrating character of limestone boulders resting on clays, surrounded by semi-flat surfaces that can be assimilated to

Figure 41. Petrella Guidi boulder.

pediments, originated by freezing and thawing cycles. In fact, the load of water that can be stored in the clays meant that they were able to transport rock blocks of considerable size over significant distances, during the last glaciation, with a behaviour very similar to that of glaciers. On the northern portion of the site, a vast marshy area dominated by landslides can be observed.

Geoscientific interests: geomorphological;

Geotypes present: boulder;

Contextual interests: landscape, historical;

Values: geotouristic;

Protection: advisable;

Accessibility: easy.

30. VMUmmv007 Pennabilli mounts (SU, geomorphosite)

The medieval village of Pennabilli is set upon the calcarenite limestones of the San Marino formation that unconformably lay on clays of Argille Varicolori formation. The name comes from the merging of two existing castles, Penna and Billi, during the XIV century when a treaty of non-belligerence was signed upon the "Pietra della Pace" (i.e., Peace Stone), now hidden under the cobblestones of the main square, in correspondence with the fountain. The two small cliffs that characterise the landscape are called Roccione and Rupe in the local tongue and are composed of hardly fractured limestones, which have a tendency to lateral spreading. Large landslides affect the slopes from which these cliffs rise; they develop radially around the inhabited area on the north-western and southern sides, affecting both the reliefs. Characteristic is the collapse phenomena, which affect the rock mass subject to slow phenomena of lateral expansion, which cause the intense and pervasive fracturing. These downstream instability phenomena evolve into complex landslides. Numerous cultural elements are remarkable in the village: a museum fully dedicated to mathematics, the naturalistic museum and visitor centre of Sasso Simone and Simoncello Park, the open-air museum "I

Luoghi dell'Anima" (i.e., places of the soul) by Tonino Guerra, the museum of Montefeltro, and typical Buddhist installations related to the history of Padre Orazio Olivieri della Penna, a monk that settled a mission in Tibet in XVIII century and compiled the Italian-Tibetan dictionary. On the top of the Roccione stands one of the Gioconda's balconies, which locates the background of the famous Leonardo Da Vinci's portrait inside the Valmarecchia landscape (Borchia & Nesci, 2021). Two rupestrian examples are located at a short distance from the geosite: Pennabilli double tub (VMUrup014) and Hermit's cave (VMUrup015).

Geoscientific interests: stratigraphic, geomorphological;

Geotypes present: landslide, cliff;

Contextual interests: historical, architectural, landscape, cultural;

Value: scientific, educational, excursion;

Protection: advisable;

Accessibility: very easy.

Registered on the ISPRA National inventory of geosites as *Rilievo di Pennabilli* (point feature).

Figure 42. Pennabilli mounts.

31. VMUstr001 Senatello-Marecchia confluence anticline (SU, geomorphosite)

Along the left bank of the Marecchia River, just downstream of the confluence with the Senatello stream, stands a rocky outcrop where the Marnoso-Arenacea formation is exposed and marked by an exemplary anticline, placed behind an overlap that lies just north of the outcrop. This site has a didactic-disseminating value for its exposure and observation possibilities along the road and the river bed. Going up the Senatello riverbed, one will find other interesting outcrops near the confluence. The anticline is located in the proximities of Ponte degli Otto Martiri (i.e., Bridge of the Eight Martyrs), referring to a Nazi-Fascist massacre that took place on this site in 1944.

Geoscientific interests: structural, geomorphological;

Geotypes present: overlap, anticline, escarpment;

Contextual interests: landscape, historical;

Value: scientific, divulgative;

Figure 43. Anticline at the confluence of Senatello and Marecchia Rivers.

Protection: advisable; partially already in place (ZSC/ZPS IT4090005 - Fiume Marecchia a Ponte Messa);

Accessibility: easy.

32. VMUstr002 Casteldelci cliff (NAT, geomorphosite)

The Marnoso-Arenacea formation emerges along the left bank of the Senatello river with excellent exposure, showing an almost perfectly horizontal stratification. The Marnoso-Arenacea formation expresses here as the member of Collina, a pelitic-arenaceous lithofacies marked by intercalation of sandstones in thin and medium beds, at times thick and very thick, with an A/P ratio of less than 1/5. It shows a sub-horizontal layering of the stratification. Morphosculptures mark the outcrop due to the erosive selection of the arenaceous and marly layers, which created a stairway between the base and the top of the cliff, called "*Ripa del Lamento*" (i.e., 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 central road system.

Geoscientific interests: geomorphological, stratigraphic;

Geotypes present: cliff, morphosculpture, stratigraphic succession;

Figure 44. Casteldelci village and the Ripa del Lamento.

Contextual interests: landscape;

Value: divulgative, excursion;

Protection: advisable;

Accessibility: medium difficulty.

33. VMUstr003 Mt. Faggiola Vecchia and Mt. Faggiola Nuova (SN, geomorphosite)

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. 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 apparent changes in morphology and plant cover, drawing neat passages between broad areas marked by soft morphologies and covered by grasslands and much steeper slopes surrounded 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 weathering, while the arenaceous ones, much more tenacious, form protruding cornices moulded into aligned pinnacles, that produce the typical sawtooth morphologies. At the top of Mt. Faggiola Nuova, the remains of the foundation walls of a castle that stood there in the 13th century can be observed. This was the home and birthplace of Uguccione della Faggiola, captain of fortune and politician of the

Figure 45. Mt. Faggiola Nuova and Santa Maria in Sasseto flat surface (in the front).

time, where it is believed that Dante Alighieri was hosted when exiled from Florence (Dominici L., 1959). Access to the site is of medium difficulty.

Geoscientific interests: structural, stratigraphic, geomorphological, sedimentological;

Geotypes present: fault, flute casts, morphosculpture, stratigraphic succession;

Contextual interests: historical, landscape;

Value: scientific;

Protection: advisable;

Accessibility: difficult.

34. VMUtec001 Sant'Alberico intra-mountain basin (SN, geomorphosite)

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 the San Marino formation. This sub-flat area was called La Cella di Sant'Alberico (i.e., 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. It is 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, while in the same direction (maybe 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. Accessibility to the site is easy.

Geoscientific interests: geomorphological;

Geotypes present: intra-mountain basin, DGSD;

Contextual interests: landscape, cultural, historical;

Values: scientific, divulgative, geotouristic, excursion;

Protection: already in place (ZSC IT4080008 - Balze di Verghereto, Monte Fumaiolo, Ripa della Moia);

Accessibility: easy.

35. VMUflv003 Senatello springs (SN, geomorphosite)

This geosite encloses the areas of Mt. Aquilone and Poggio del Passino reliefs, from which the Senatello river springs. The water source is held within a capture work dating back to 1920 that initially diverted the flow towards the Savio valley, while 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 stream that testifies to the extraordinary flow rate 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 composed of the limestones of the San Marino formation, topped by the sandstones of Mt. Fumaiolo formation, 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 act 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. A legend associated with the Senatello springs tells how the running tears of a warrior of the XIII century, who received the pardon of God on a big rock in the proximity of the springs, are still flowing and feeding the river[18].

Geoscientific interests: hydrogeological, geomorphological;

Geotypes present: natural spring, pyramidal relief;

Contextual interests: landscape, cultural;

Values: scientific;

Protection: not necessary;

Accessibility: easy.

36. MTFstr004 Pietrafagnana mount (NAT, geomorphosite)

Pietrafagnana and Pietrarubbia conglomerates are a unique feature in the Montefeltro region. Observed from close up, these rocky spurs are made up of rounded pebbles cemented together, part of conglomerate levels interspersed inside the Colombacci formation, most of which are combined into a single large body several tens of metres thick (Farabegoli & Ricci Lucchi, 1973). It appears dislocated in various blocks by minor faults and characterises the summit position of the Messinian section, representing an important and characteristic geomorphological and landscape element. They have an arenaceous matrix,

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

Figure 46. Pietrafagnana mount.

sometimes marly, with intercalations of poorly cemented sandstones. Natural weathering processes have acted on the rocks, causing the detachment of pebbles. The tallest spur is known as Dito del Diavolo (i.e., Devil's finger) or Dito del Gigante (i.e., Giant's finger), a place of ancient and mysterious legends, also due to the fact that the finger appears to be struck by lightning and thunderbolts during storms. In the past, it was possible to hear the "lament of the Giant", a sound most probably due to the passage of air through a naturally formed hole, that had strengthened the legends even more. The place could also hide a secret (or a treasure) of the devil himself. In fact, another legend tells how this is the exact spot where God made Lucifer fall, after chasing him out of Paradise for disobeying him. A XIV century document mentions a certain Lord of Pietrafagnana, but there is no information about this Castle. This rocky outcrop could therefore have been a human fortification but, to date, nothing remains of the castle.

Geoscientific interests: geomorphological, sedimentological;

Geotypes present: rock pillar;

Contextual interests: landscape, cultural;

Values: scientific, geotouristic, excursion;

Protection: already in place (ZPS IT5310026 - Monte Carpegna e Sasso Simone e Simoncello);

Accessibility: easy.

37. MTFstr005 Pietrarubbia mount (SN, geomorphosite)

Pietrarubbia, "a village of soft stones that caress the eyes" by using poet Tonino Guerra's words, rises on top of the conglomeratic lithofacies of Colombacci formation, and the toponym itself derives from the characteristic macroscopic shade of this geological feature (from Latin *petra rubea*, i.e., red stone). As the nearby Pietrafagnana, the conglomerates have an arenaceous matrix, with intercalations of poorly cemented sandstones. The sediments are most probably been deposited in a semiarid environment (De Feyter & Molenaar, 1984) and are representative of the Upper Messinian depositions of Marche region. On the top

Figure 47. Pietrarubbia mount and castle ruins.

of the mount, the ruins of the ancient castle of Pietrarubbia can be found, and testimony an important castle founded in the early Middle Ages, around the middle of the XIII century. As evidence of the ancient fortress, in addition to the tower known as the Torre del Falco (i.e., Falcon tower), the stones used for firearms and equipped with notches can be observed walled up in the houses of the village. At the beginning of the 1970s, the sculptor Arnaldo Pomodoro renovated the village, raising the awareness of local institutions with the aim of founding a school on the art of metals, born in 1990. Today, several of his works can be seen in various buildings in the village.

Geoscientific interests: geomorphological, sedimentological;

Geotypes present: rock pillar;

Contextual interests: landscape, historical, cultural;

Values: scientific, geotouristic, excursion;

Protection: already in place (ZPS IT5310026 - Monte Carpegna e Sasso Simone e Simoncello);

Accessibility: easy.

38. VMUflv004 Tevere springs (NAT)

The Tiber River originates from two spring areas located along the northern slope of Mt. Fumaiolo, at 1,268 m a.s.l. The perimeter of the geosite comprises the location of the most abundant area of spring waters, which are deeply linked to the ancient urban settlements of Rome and have been marked since the thirties by a local travertine column overlooked by a golden eagle. Depending on the territories crossed by its waters, the Tiber River has assumed different names over the centuries, such as Albula (Plinio il Vecchio, Naturalis Historia, III, 53), Serra, Tarentum, Coluber, Rumon, from which the names of Romulus and Rome probably derive. Moreover, according to an ancient Roman legend, the name Tiber derives from Thybris, in memory of Tiberino Silvio, Aeneas' descendant

(Moretti L., 2014), who died drowned in its waters. The Tiber has always been considered a historical watercourse, a river museum.

Geoscientific interests: hydrogeological;

Geotypes present: natural spring;

Contextual interests: landscape, cultural;

Values: scientific, divulgative, geotouristic, excursion;

Protection: already in place (ZSC IT4080008 - Balze di Verghereto, Monte Fumaiolo, Ripa della Moia);

Accessibility: easy;

Registered on the ISPRA National inventory of geosites as *Vene del Tevere* (point and polygon feature).

39. VMUmmv008 Mt. Fumaiolo relief (NAT, geomorphosite)

Mt. Fumaiolo relief is an extensive rocky buttress that reaches 1,407 m asl. The sandstones of the Monte Fumaiolo formation outcrop on the western and southern slopes, as the reference area for the formation. One can observe the

Figure 48. Mt. Fumaiolo relief close to Balze village.

passage to the San Marino formation along the southernmost wall. Towards the North-West portion, large boulders mobilised by the rock-debris layer mark the surface of a landslide. In the area known as I Sassoni (i.e., 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 an active and quiescent landslide head, characterised by a complex movement developed in the clayey units below. The toponym Fumaiolo can derive Fiumaiolo (from the Italian word *fiume*, meaning river) for the conspicuous springs that flow along and around its slopes.

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: stratigraphic, geomorphological;

Geotypes present: landslide, buttress, stratigraphic succession, reference area;

Contextual interests: landscape;

Values: scientific, divulgative, sport climbing, excursions, geotourism;

Protection: already in place (ZSC IT4080008 - Balze di Verghereto, Monte Fumaiolo, Ripa della Moia);

Accessibility: easy.

Registered on the ISPRA National inventory of geosites as *Monte Fumaiolo* (point and polygon feature).

40. VMUstr006 Molino di Bascio cliff (NAT, geomorphosite)

At Molino di Bascio, the left side of the Marecchia Valley is marked by particularly extensive outcrops, where the rhythmic alternation of arenaceous and marly layers, typical of the Marnoso-arenacea formation, is exposed. The rocky walls are crossed by a particularly thick layer, a significant example of a guide layer, called Contessa layer in reference to the Valle della Contessa, near Gubbio, where it emerges with its maximum thickness. This is probably the most important guide layer of the northern Apennines, being the first recognised guide layer in this formation and having an extraordinary extension, since it can be followed uninterruptedly for over 150 km. Starting from Umbria, it extends through Marche and Romagna, with a progressive decrease in thickness. In the Romagna valleys, the recognition of the Contessa is relatively easy since it has a truly extraordinary thickness, particularly in its marly part, light grey, which can reach 8 metres. In contrast, its sandy part, beige-brown in colour, varies between 3 and 5 metres. It has been hypothesised that its deposition took place following an important seismic event during the Upper Langhian (14 million years ago), which would have caused enormous quantities of sediment to be suspended in the water. Along the opposite side of the valley, at the top of a hillock, there is the village of Bascio, overlooked by the tower of the same name, the witness of a large castle dominating the Marecchia Valley, dating back to the XIII century. Bascio was a fundamental passage along the Ariminensins road, leading from Rimini to Rome, as testified by the popular saying "we will go to Rome if God wills it and those of Bascio too", attributed to the pilgrims who travelled along the road. The remains of the castle are few; at the foot of the tower, alignments of the ancient walls and a moat, now dry, can be seen. At the foot of the tower is the Giardino Pietrificato (i.e., petrified garden) of Tonino Guerra: seven ceramic carpets dedicated to the same number of people from the past who have lived in or passed through these places.

Geoscientific interests: geomorphological, stratigraphic, sedimentological;

Geotypes present: morphosculpture, stratigraphic succession, fluvial erosion scarp, sedimentary structures;

Contextual interests: architectural, historical, cultural, landscape;

Value: divulgative, geotouristic;

Protection: advisable;

Accessibility: easy.

41. VMUcav003 Miratoio peak (SN, geomorphosite)

In the relief of Poggio Miratoio, consisting of calcarenites of the San Marino formation, there are several natural cavities, small in size and originating from the widening of fractures or minor faults due to the force of gravity, which led to the slippage and progressive removal of the rocky blocks. The evolution over time of this phenomenon has allowed the formation of small rooms. The "Tana di Barlaccio" or "Antro di Barlac" (i.e., Barlaccio or Barlac's shelter) is the biggest and more accessible one, located on the north side of the relief, at about 900 m asl, right under the ancient Miratoio Castle location, of which every testimony is now lost. The cave has a trapezoidal entrance and is due to an important fracture that has deeply governed the disarticulation of the rock formation. The intersection between the fracture plane and other weak surfaces, such as those of stratification, has facilitated the collapse of rocky blocks, determining a large part of the cavity. At the end of World War II, the cave was the refuge for some soldiers who had escaped from a prison camp and were literally fed for several months by the people of Miratoio. Inside this cave is located the rupestrian evidence Barlac's seat (VMUrup016). The cave of Beato Rigo is a notorious cavity because it was, by tradition, the hospice and place of penance of the hermit Beato Rigo (short for Arrigo or Enrico), who lived in the XIV century. Inside the cave, a step in the shape of a kneeler is located. Elderly residents testify that, before some collapses, the cave would have been much more developed. The cave called "Tana Buia" (i.e., dark burrow) is characterized by two impervious and uncomfortable entrances. During the Second World War, the cave became a shelter for the goods of the Miratoio families, who were forced to abandon the village temporarily. Witnesses tell of another cave called "Spacco del Diavolo" or "Grotta dei pipistrelli" (i.e., devil's cleft or bat's lair), 40 metres long and located at 865 m asl above the present village, with access obstructed by debris. The cavities in Miratoio offer an ideal habitat for the speleomantes italicus, a rare and protected amphibious. From the top of Miratoio relief, one can have a beautiful view over

Figure 49. Miratoio peak and house without a door.

the upper Marecchia Valley, extending towards Sasso Simone and Simoncello. Very characteristic are the numerous carvings in the rock walls in the proximity of the village, and the little house standing right in the middle of a rock wall, without any stairs or access road, and without a door.

Natural cavities are included in the area or in the proximities of the geosite.

Geoscientific interests: geomorphological;

Geotypes present: natural cavity, cliff, sedimentary structures;

Contextual interests: historical, landscape, fauna;

Values: divulgative, geotouristic, excursion;

Protection: already in place (ZSC/ZPS IT4090006 - Versanti occidentali e settentrionali del Monte Carpegna, Torrente Messa, Poggio di Miratoio);

Accessibility: easy.

42. VMUmmv009 Sasso Simone and Simoncello (SN, geomorphosite)

The area of Sasso Simone and Simoncello is very representative of the Valmarecchia Nappe. The two calcarenite reliefs (San Marino formation) lean on a massive extension of clays of the Brecce Poligeniche di Sasso Simone formation (i.e., polygenic breccias of Sasso Simone), outcropping to the South in the gullies

Figure 50. Sasso Simone cliff and a calcareous boulder on clayey formations (in the front).

of the Torbello Creek. The San Marino formation consists of grey organogenic limestone and greyish-white limestone rich in bioclasts. The rocks preserve fragments or intact remains of bryozoans, calcareous algae, rhodolites, echinoids, molluscs (ostreids and pectinids) and macro foraminifera. The less carbonate and more sandy levels are frequently bioturbed with recurrent fossil traces. The stratification is concave-convex, sometimes parallel, undulating and crossed with megaripples. These structures indicate sedimentation on shallow seabeds affected by tides, coastal currents and storm waves. The calcarenite becomes silty-sandy and glauconitic towards the top, where the gradual passage to the overlying sandstones of the Monte Fumaiolo formation is observed, indicating an increase in the terrigenous contributions that close the carbonate depositional system. The contrasts of erodibility between the basal clayey units and the more competent calcareous units above give rise to isolated reliefs, bordered by sub-vertical slopes. Therefore, these cliffs rise with considerable energy on the surrounding slopes with a weak acclivity, marked by gullies and landslides. The Sassi slopes have two very different sides: to the North, the clayey slopes are scarcely steep and densely covered by a large forest, which exceeds 800 hectares, constituting the biggest turkey oak (Quercus cerris) forest in Europe. Thanks to the presence of clayey soils, the specimen exceeds its altitudinal limit, reaching an altitude of 1.100 m asl and occupying the altitudinal belt of the beech tree. The undergrowth of the forest is rich in numerous protected species. On the other hand, there are extensive gully basins towards the South, which form the heads of the Torbellino Creek and the Seminico Creek. Exemplary and well recognisable, both from far and near, are the forms that indicate the phenomena of lateral spreading of the rigid rocky buttresses on the underlying clays, with an evident stretching of the structure and the consequent formation of cracks, hollows, valleys that open on the summit plains and along the walls of the Sassi. One of the most characteristic geological features is the development of a massive complex landslide, which originates from the southern edge of Sasso Simone, where enormous blocks are dislocated by rock falls and topplings from the cliff and, resting on the clayey units, begin their journey downstream, creating a "river of boulders" that extends for 1 km ca. The dominant position interested the Malatesta family first, and then Cosimo I de Medici built a fortified city on top of the Sasso Simone, called Città del Sole (i.e., City of the Sun), on the border between the Grand Duchy of Tuscany and Montefeltro. The city had a brief fate dictated by the severity of the climate changes which followed the onset of the Little Ice Age. Few remains of the city can be observed, such as the road that leads to the top of the relief, renovated in the 1990s, or the city water cistern on the top.

Geoscientific interests: geomorphological, stratigraphic, sedimentological;

Geotypes present: gullies, natural cavities, cliffs, stratigraphic succession, sedimentary structures;

Contextual interests: historical, botanical, fauna;

Value: scientific, educational, excursion, geotouristic;

Protection: already in place (EUAP0969 - Parco Interregionale Sasso Simone e Simoncello; EUAP0401 - Riserva Naturale Regionale Sasso di Simone; ZSC IT5180008 - Sasso di Simone e Simoncello; ZSC/ZPS IT4090006 - Versanti occidentali e settentrionali del Monte Carpegna, Torrente Messa, Poggio di Miratoio);

Accessibility: medium difficulty.

Registered on the ISPRA National inventory of geosites as *Sasso di Simone e di Simoncello* (point feature).

43. VMUflv005 Marecchia springs (NAT, geomorphosite)

The springs of the Marecchia River are located at 1,263 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. 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, one can 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 broad head, beyond which the upper Tiber valley opens up. The marly rocks of the Vicchio formation are evident along this watershed, exposed in the gully incisions that interrupt the meadows and become badlands. Here, vegetation is fragile; the juniper is a sign of a poorly evolved and complicated 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.

Geoscientific interests: hydrogeological, geomorphological;

Geotypes present: gullies, spring;

Contextual interests: landscape, cultural;

Value: excursion, geotouristic;

Protection: advisable;

Accessibility: easy.

4.3.1 Republic of San Marino geosites

The geosites of the Republic of San Marino have been firstly identified in the Framework Law for the Protection of the Environment, and the Safeguarding of the Landscape, Vegetation and Flora (n. 126/95), and they are included in the Comprehensive Plan of Protected Naturalistic Areas of 2010.

Although their protection is officially recognised, few actions of enhancement or valorisation have been taken. The following descriptions are intended as a first step in their cataloguing, although not sufficient to include them in the broader context of enhancement actions for the Marecchia Valley and Montefeltro historical region territories.

44. RSMmmv010 San Michele boulders (SU): area where massive calcareous boulders of San Marino formation (SMN) lie upon a semi-flat or slightly sloping terrain on clayey formations, which can be identified as a pediment surface.
45. RSMrel012 Acquaviva cliff (SN, geomorphosite): typical rocky cliff in the San Marino formation (SMN), with a historical water spring at its base, due to stratigraphic contact between the impermeable clays and the highly fractured calcarenites above them, which gave name to the toponym Acquaviva (i.e., living water).
46. RSMfos001 Casa i Gessi fossil site (NAT): an area where numerous fossils and fragments from marine shells can be found in the Messinian clays of the Argille di Casa i Gessi formation (CGE), among badlands.

Figure 51. Rock pillar on Casa i Gessi formation.

47. RSMcha001 Casa i Gessi chalks (NAT, geomorphosite): outcropping of selenitic gypsum of the Gessoso-Solfifera formation (GES), lying upon the badlands cut into the Argille di Casa i Gessi formation (CGE).
48. RSMrel013 Baldasserona cliff (NAT, geomorphosite): calcareous rocky cliff cut in the San Marino formation (SMN) with numerous nivation hollows; inside one of them, in the stone wall, the rupestrian evidence of San Marino's bed (*Sacello del Santo Marino,* RSMrup002*)* is located and can be reached after climbing a steep staircase carved into the rock.
49. RSMrel014 Mt. Titano ridge (NAT, geomorphosite): massive calcareous rocky buttress, where the complete stratigraphic succession of Epiligurian carbonatic plates is represented. A series of important debris cones characterise the bottom, now almost completely vegetated but clearly visible in historical pictures of the cliff. Nivation hollows are present, and many fractures in the calcareous blocks give origin to caves, such as the *Tanaccia* (i.e., burrow, which is an archaeological

Figure 52. Mt. Titano ridge with the iconic three castles on top and coalescent debris fans.

site) and the *Genga del Tesoro* (i.e., treasure boulder). The close link between the Republic and its mountain, Mount Titano, and its rocks, justified its inclusion in the list of UNESCO World Heritage Sites, together with the historic centres of Città di San Marino and Borgo Maggiore, in 2008.

50. RSMmmv011 Ca' Rinaldo badlands (NAT): area where badlands are cut into the Pliocene formation of the Argille Azzurre (FAA).
51. RSMrel015 Mt. Cucco cliff (NAT): a typical calcareous cliff in the San Marino formation (SMN).
52. RSMstr007 Mt. Cucco and Pietraminuta ridge (NAT): interesting mountain ridge where Epiligurian rocks in stratigraphic sequence follow one another rapidly in a limited outcropping area.
53. RSMflv006 Canepa creek and Montecchio gorge (NAT, geomorphosite): interesting torrential trait set on fractures of the calcareous blocks of San Marino formation (SMN), characterised by small waterfalls, potholes, karst phenomena

(Canepa caves, or *Grotte di Canepa*) and historical watermills (i.e., *Molini di Canepa*).

54. RSMkar003 La Casetta doline (NAT): surface karst features set on fractures of the San Marino formation (SMN).
55. RSMflv007 Zoppa creek gorge (NAT): small gorge with exemplary potholes.
56. RSMflv008 Gorgascura gorge (NAT): the bigger of the listed gorges.

Figure 53. Gorgascura gorge.

57. RSMmmv012 Maiano and Maiano creek (SN): area where massive calcareous boulders lie upon clayey formation, cut with badlands.
58. RSMfos002 La Bosca fossil site (NAT): interesting fossil site on the Pliocene Argille Azzurre formation (FAA), which constitutes an isolated outcropping embedded in between thrust lines in the Argille Varicolori formation (AVM).
59. RSMrel016 Faetano cliff (NAT): rocky cliff constituted of macrocrystalline selenitic gypsum.

60. RSMrel017 Fratta rocky slab (SN): portion of San Marino formation (SMN) outcropping, with an archaeological site above it.
61. RSMflv009 San Marino creek from Monte Castellaro to Scaldabò (NAT, geomorphosite): particularly interesting trait of the San Marino creek, where badlands on clayey terrains and massive calcareous blocks can be observed.
62. RSMstr008 Monte Castellaro cliff (SN): calcareous rocky cliff in the San Marino formation (SMN); the geological limit with the Argille Varicolori formation (AVR) is unconformably outcropping at the base of the cliff.
63. RSMmmv013 San Marino creek badlands (NAT): badlands along the San Marino creek, cut in the Argille Varicolori formation (AVR).
64. RSMflv010 Chiesanuova creek gorge (NAT): small gorge on the Chiesanuova creek, set upon fractures in the Monte Morello formation.
65. RSMrel018 Pennarossa cliff (SU, geomorphosite): calcareous rocky cliff in the San Marino formation (SMN), particularly interesting as it hosts various age settlement ruins and a series of rupestrian evidence of unknown origin and age (i.e., Pennarossa tubs, RSMrup003).
66. RSMmmv014 Liscari badlands (NAT): badlands cut in the Argille Varicolori formation, particularly interesting for the outcropping of plication structures in the clays.
67. RSMmmv011 Pianacci creek badlands (NAT): typical badlands cut in the Argille Varicolori formation.
68. RSMcha002 Montegiardino chalks (SN, geomorphosite): beautiful examples of outcropping macrocrystalline selenitic gypsum surrounded by a karst complex, where dolines, sinkholes and underground traits of the Marano creek can be observed.

4.3.3 Valmarecchia rupestrian tubs

The geological points of interest of the *Vasche rupestri della Valmarecchia* have been mapped to highlight a scarcely known feature, which could, in turn, become distinctive for the whole area Valmarecchia and Montefeltro as an example of interaction between man and geological landscape. Their potential for geotouristic purposes is still unknown but could involve a wide audience, consisting not only of people with interest in geological subjects but also in historical, cultural and even mistery topics.

69. VMMrup001 Madonna's seat

    Small-sized rock seating on a calcareous boulder, known as "Madonna's seat". Traditionally, Mary, mother of Jesus herself, to whom the sanctuary is dedicated, was responsible for the peculiar seat, as she was seen in the proximities of the church.

70. RSMrup002 San Marino's bed

    The traditional "home" in which San Marino rested is shaped in a series of nivation hollows set on an interlayer in calcarenites, known as "Sacello del Santo Marino". This is an important example of how a geomorphological element can become symbolic and be an identity value for a place.

71. RSMrup003 Pennarossa tubs

    Located where the ruins of the ancient settlement of Pennarossa are standing, this surprising complex of various tubs and channels is poorly studied and of unknown age and origin, but their functional use rather than ritual purpose seems the best hypothesis, also considering the presence of an important castle on the site.

72. VMMrup004 San Leo tub

    One of the most outstanding examples of rock-cut tubs is located at the top of the village of San Leo, in between the main church and the bell tower. The tub is rectangular in shape, with numerous cupel shaped cavities, channels and carvings in its borders. Significant is also the presence of rupestrian carvings on the calcareous outcropping behind the bell tower, which testify to the most likely ritual use of the site (Battistini & Battistini, 2011). The area is enhanced with didactic panels about the rupestrian complex.

73. VMMrup005 Masso del Tino tubs

A peculiar boulder that hosts three different carved tubs, commonly known as Masso del Tino (i.e., vat boulder). The probably most ancient one is now standing vertically along the path that brings to the top of Mt. Fotogno, a position that suggests the mobilisation of the boulder most probably due to a rock-fall, which relocated it from its original position (Veggiani A., 1984). On the top of the boulder is located a triangular-shaped tub, connected to a lower one through a small channel.

Figure 54. Masso del Tino vertical tub.

74. VMMrup006 Mt. Fotogno tub

This tub is located at a short distance uphill from Masso del Tino, most probably in the proximities of the ancient Monte Fotogno castle (Lombardi F.V., 1999). The tub has been broken in half, maybe after falling from a higher position. It was found and restored in January 2020.

75. VMMrup007 Tausano tub

Small-sized closed tub, located along Mt. Gregorio crest, on the trek which follows the Tausani ridge. From this point, one can view the historic Tausano landslide from above and observe the lithological contact between the arenites of Monte Fumaiolo formation (MFU) and conglomerates of Acquaviva Formation (AQV).

76. VMMrup008 San Paolo's bed

Massive rupestrian tub of the open type, commonly known as *Letto di San Paolo*. It is located in the proximities of the Rasino creek (a right tributary to the Marecchia River) on a boulder coming from the Maiolo cliff, rising above it. It is characterised by small channels and holes on the sides and stairs on the back portion of it, which help climb the structure. Carvings mark other boulders in the same area, and a small cave is located a couple of hundred meters north of the site, with a peculiar levigated stone fixed in the ground at its entrance.

77. VMMrup009 San Marco's tub

This beautiful example of a rupestrian tub has been luckily preserved from the intense quarrying activity that shaped Mt. San Marco to its current aspect. It is rectangular in shape and without any openings and characterised by a series of small stairs in the borders and numerous cupel shaped cavities and carvings. It is located where the ancient castle of Monte Acuto stood, but no remains are found, except the basement of a tower, located slightly uphill from the tub.

78. VMMrup010 Pope's seat

Single tub traditionally known as Sedia del Papa (i.e., Pope's seat), which is part of the remains of Montecopiolo castle. This medieval settlement has been interested by deep investigations and archaeological excavations, which gave a functional interpretation for the tub, as it could have been a filtration tank for a cistern located underneath (Ermeti & Sacco, 2003).

Figure 55. San Marco's tub.

79. VMMrup011 Torricella double tub

Double tub, located in the woods close to Torricella village on an isolated boulder. The top-most tub is irregular in shape and characterised by little channels and holes along the borders. The smaller one, located underneath the first and connected by a small canal, is rectangular in shape.

80. VMMrup012 Ville di Monte Benedetto tub

Open tub now almost entirely hidden by vegetation. It is said that a rock displacement from this site originated San Silvestro's bed.

81. VMMrup013 San Silvestro's bed

Open tub, traditionally known as San Silvestro's bed or Sant'Ottaviano's bed, broken into two parts. After a rockslide that affected the slope, it originated from the Ville di Monte Benedetto tub.

82. VMMrup014 Pennabilli tub

Double tub carved in a boulder at a short distance from Pennabilli village, both rectangular and connected by a drainage hole. The shape resembles the ones

Figure 56. Ville di Monte Benedetto tub.

traditionally used for vinification (Battistini & Battistini, 2011). However, the name of the locality in which the tub is located (La Concia, i.e., tanning procedure for leather) could suggest a possible functional use.

83. VMMrup015 Hermit's cave

    A small shelter has been carved into a boulder located inside a small forest, in locality Santa Colomba of Pennabilli village. The hut is traditionally said to be used as a hermitage site, but by whom and in which age is unknown.

84. VMMrup016 Barlac's seat

    The sit is located inside a non-karstic cave almost on the top of Miratoio mount. The cave was used ad a shelter by soldiers at the end of WWII; thus, its age could be very recent.

85. VMMrup017 Tabussa tub

    This peculiar tub is located inside a non-karstic cave, and water spillage from a natural spring inside of it caused the formation of calcareous concretions. Unique in this feature, unfortunately, the cave entrance is now banned for security reasons.

Figure 57. Hermit's cave.

Figure 58. Tabussa tub.

CHAPTER 5.

DISCUSSION AND RESULTS

This chapter summarises the results of the actions proposed for the geological and geomorphological enhancement of the study area, referring to the geomorphological map, the quantitative geomorphological analysis, and the digital and live valorisation of the geological landscape. Finally, a comparison between the latter two topics is proposed.

5.1 GEOMORPHOLOGICAL MAP

As already mentioned in Chapter 2 Materials and Methods, geomorphological mapping and quantitative geomorphic analyses have been the first fundamental tools to know and interpret the values of geological landscape, as they provided an overview of the entire Marecchia valley.

The main character evidenced by the *Geomorphological Map* is the presence of landforms in solid relation to human settlements, which give them additional valuable features. They reflect the importance attributed to those territories in past centuries. Therefore, analysing the historical or contemporary human landscape context cannot be separated from considering the geomorphological aspects. The geomorphological study allowed to map the main landforms and reconstruct some of the morpho-evolutionary phases in upper Pliocene-Pleistocene, through the analysis of relict paleosurfaces, which are representative of non-equilibrium features that result from surface uplift and successive degradation attributable to weathering (Guerra & Lazzari, 2020).

The geomorphological map includes the main landforms of the study area, such as erosional paleosurfaces, deeply seated gravitational slope deformation (DGSD) areas and trenches, active and inactive landslides and detachment crowns, the hierarchical hydrographic network and main riverbeds, abandoned river channel traces, stream terraces, badlands, alluvial fans, and cliffs prone to rockfalls. Anthropic landforms are also present in the area, such as active or inactive quarry sites or landfills.

Landforms appear strongly influenced by the outcropping lithotypes. In the case of slope processes, Argille Varicolori formation (AVR) and Sillano formation (SIL) favour the development of badlands, as the result of interaction between argillitic formations and linear erosion of surface runoff. Otherwise, they are interested by mudflows and debris-flows phenomena. Solifluction, rock-slides or vast deep-seated gravitational slope deformations occur primarily in correspondence with the flysch of Monte Morello formation (MLL). In contrast, the more massive configuration of the calcarenite lithotypes, such as San Marino formation (SMN), Acquaviva Formation (AQV) and Monte Fumaiolo formation (MFU), contribute to the development of rock-falls, topplings and complex landslides, often favoured by the presence of the argillitic formation at the bottom of the calcareous wedges. This lithological contact results in intense erosion of the basement of the blocks above, thus resulting in vertical cliffs and isolated rock pillars. This characteristic is extremely common in the study area and could be one of the main factors in determining the diffusion and severity of hydrogeological instability, especially during the Quaternary glaciations and cold phases in historical times (Guerra & Nesci, 2013), with an acme during the Little Ice Age (Fagan B.M., 2001).

5.2 Geoheritage online atlas

The most valuable information obtained when compiling the geomorphological map has been made suitable for online publication through a dedicated Google My Maps, with the meaning of building a publicly accessible digital atlas for geomorphological features, including some aspects related to geotourism.

The elements represented on the *Paesaggeo* My Maps online map[19], which functions as a Geoheritage Atlas of Valmarecchia and Montefeltro, are the following:

- geosites of regional and local value (established by Emilia-Romagna region);
- geosites of the Republic of San Marino;
- newly proposed geosites identified in this research;
- protected areas (SIC-ZSC, ZPS, EUAP protected sites);
- geologically significant trails experimented during *Paesaggeo* geotourism proposal of 2021;
- rupestrian evidences;
- Marecchia watershed;
- alluvial plain;
- floodplain and recent terraces;
- landslides;
- active badlands and areas in retrogression;
- erosional paleosurfaces.

5.3 Short term erosion rates

The morphological analysis has been conducted on two sample areas in the middle and upper Marecchia valley. The Mazzocco and Senatello sub-basins are, respectively, on the right and left sides of the main watercourse and represent the geological, geomorphological and hydrological characters of the valley. They have similar average steepness of the longitudinal profiles, equal to 6.65% for the Senatello River and 6.79% for the Mazzocco River.

[19] *Paesaggeo* My Maps online map https://bit.ly/3473onL

Fluvial morphologies in the Marecchia and Mazzocco river valleys are characterised by braided channels, according to hydraulic parameters related to the riverbed slopes (Pizzuto J., 2011). The hydrographic network has an order of 5 (Strahler A.N., 1957) and has a drainage density value of 3.66 (Avena et al., 1967; Ciccacci et al., 1980), compatible with a prevalent clayey-marly substrate on the entire basin.

Quantitative geomorphic analysis was based on the morphometric study of the drainage network, which allowed the calculation of several significant parameters to state the efficacy of the morphogenetic processes quantitatively and assess the short-time erosion rate. Quaternary tectonics has influenced the hydrographic network, especially in the Senatello river, as it has controlled the orientation and distribution of some channels of the hydrographic network (straight development, river elbows, high confluences angle, capture phenomena and convergence of river streams, countercurrent tributary branches), qualitatively highlighted by some anomalies of the hydrographic network.

In general, quite similar values result from the quantitative analyses of Senatello and Mazzocco river networks. The most meaningful geomorphic parameters are an expression of the state of morpho-tectonic maturity of the basin, such as the bifurcation index and ratio (Rb, Rbd, R), which represent the state of hierarchical organisation of the network. Values have been found greater for the Mazzocco basin (see Table 9). Indications of tectonic influence on the flow of water can be obtained from the calculation of morphometric parameters that quantitatively describe the organisation of the hydrographic network. The trends of the minor waterways (1st and 2nd order in Strahler's hierarchy) generally show a good correspondence with the families of faults and fractures that pervade the rocky bodies more widely.

Elongation and circularity ratios (Rf and Rc) depend on the geomorphological features' evolutionary stage and describe the basin's geometry (Table 9).

Drainage density (D) and hierarchical anomaly index (Δa) are representative of drainage network features that strongly affect denudation intensity. (Melton, M.A., 1957; Ciccacci et al., 1979; Zingaro et al., 2019).

The Senatello river hydrographic network has an order of 6 (*sensu* Strahler A.N., 1957) and has a drainage density value of 3.85 (Ciccacci et al., 1980; Avena et al., 1967), whilst the Mazzocco has an order of 5 and a drainage density value of 3.66; both values are compatible with a prevalent clayey-marly substrate on the entire basin surfaces. According to the classification given by Smith K.G., 1940, the drainage density can be classified as "coarse", falling in the low-density category. Values greater than 3 of the bifurcation ratio (Rb, Table 7) indicate a somewhat disorganised hydrographic network geometry, typical of the areas controlled by tectonics and characterised by lithological heterogeneity.

Mazzocco	**N_u**	**N_{du}**	**Rb**	**Senatello**	**N_u**	**N_{du}**	**Rb**
1st order	323	241		**1st order**	334	256	
			4.31				4.02
2nd	75	47		**2nd**	83	56	
			3.95				4.37
3rd	19	14		**3rd**	19	15	
			3.17				3.80
4th	6	6		**4th**	5	4	
			6				2.50
5th	1			**5th**	2	2	
				6th	1		
Total	**424**	**398**		**Total**	**443**	**333**	
Mean value			**4,36**	**Mean value**			**3.67**

Table 7. Nu, Ndu and Rb values counts for Mazzocco and Senatello river basins.

However, the considerations about the hierarchy degree of the hydrographic network, deductible from the bifurcation ratio, must be verified; in fact, this parameter considers only the total number of segments in the different orders and does not always provide univocal indications (Avena et al., 1967). The structure and organisation of the fluvial network can therefore be better investigated through the direct bifurcation ratio (Rbd), as this parameter is influenced by the relationships between the confluent fluvial segments. The index provides indications of the average structure of the anomalous portion (segments of order *u* that do not flow into segments of order *u +1*). It assumes values close to zero in cases of poor tectonic activity (well hierarchical hydrographic network with segments of order u that regularly flow into those of an immediately higher order). At the same time, it approaches or exceeds values of 2 for a network influenced by the deformation pattern.

The information deductible from the bifurcation index can be integrated from that obtained from the number, the index and the density of hierarchical anomaly that are most suitable for comparison between different river basins, as in the case study.

The Δa values greater than 1 suggest a possible structural control on the drainage networks. In contrast, the ga values (<10) indicate moderate slope processes and confirm that most of the hierarchically anomalous influences are due to 1st and 2nd order streams, which flow into the main waterways (Table 8 and Table 9). Such a configuration is undoubtedly linked to control by the tectonics on the organisation of the drainage network. Denudation rates have been indirectly calculated in terms of mean annual suspended sediment yield (Tu, Ciccacci et al., 1980). Previous works demonstrated that the indirect estimation of mean yearly suspended sediment yield (Tu) obtained by the geomorphic approach is consistent with short-term denudation rates estimated by reservoir sedimentation and field monitoring data of erosion (Della Seta et al., 2007; Della Seta et al., 2009).

<u>Mazzocco</u>	**Anomalies number**				**Anomalous frequences**			
	N 1-3	N 1-4	N 1-5		F 1-3	F 1-4	F 1-5	
	32	30	19		32	90	133	
	N 2-4	N 2-5			F 2-4	F 2-5		
	14	13			28	78		
	N 3-5				F 3-5			
	5				20			
<u>**Senatello**</u>	**Anomalies number**				**Anomalous frequences**			
	N 1-3	N 1-4	N 1-5	N 1-6	F 1-3	F 1-4	F 1-5	F 1-6
	44	18	3	7	44	54	21	105
	N 2-4	N 2-5	N 2-6		F 2-4	F 2-5	F 2-6	
	11	8	6		22	48	84	
	N 3-5	N 3-6			F 3-5	F 3-6		
	2	2			8	16		
	N 4-6				F 4-6			
	1				8			

Table 8. Anomalies number and anomalous frequencies of Mazzocco and Senatello river basins.

<u>**Basins**</u>	N_u	N_{du}	**A**	**∑L**	**D**	**L**	**Rf**	**Rc**	**Ru**	**Ra**	**S**
Mazzocco	424	308	46.6	171	3.67	13.6	0.25	0.50	1.43	0.57	0.40
Senatello	444	331	48.5	186.9	3.85	11.2	0.39	0.62	1.43	0.70	0.42
	P	**F1**	**Rb**	**Rbd**	**R**	**Ga**	**Δa**	**ga**	**log Tu**	**Tu**	**Ta**
Mazzocco	34.5	6.93	4.36	3.51	0.85	381	1.18	8.18	2.71	509.75	0.20
Senatello	35.3	6.89	3.67	2.76	0.92	410	1.23	8.45	2.75	562.53	0.22

Table 9. Geomorphic quantitative parameters in Mazzocco and Senatello river basins.

The studied drainage basins showed a limited range of denudation rate index (Tu) values, between about 509 and 562 t/km^2/year (Table 9).

Starting from the Tu values, the denudation height or erosion rate (Ta) has been calculated, considering the average density of outcropping rocks of sample areas, obtaining very similar erosion rates for the two river basins, respectively, 0.20 mm/yr for Mazzocco and 0.22 mm/yr for Senatello (Table 9).

Further quantitative analyses were carried out to evaluate better the data collected for the Mazzocco and Senatello river basins.

The same studies were performed on the hydrographic network of the highest part of the Marecchia River and the Presale and San Marino creeks, as reported in the tables below (Tables 10 to 12).

As can be observed, values of Tu and Ta for the Presale creek are comparable with the Mazzocco and Senatello basins, while in the other two cases, they are much lower, as the river network is less developed. For the calculation of Ta, a value of 2.5 was chosen as the average density of the soils crossed.

Marecchia	**N_u**	**N_{du}**	**Rb**	**Presale**	**N_u**	**N_{du}**	**Rb**	**San Marino**	**N_u**	**N_{du}**	**Rb**
1st order	181	135		**1st order**	343	213		**1st order**	167	132	
			4.21				4.64				3.88
2nd	43	31		**2nd**	74	56		**2nd**	43	38	
			4.78				4.93				7.17
3rd	9	8		**3rd**	15	11		**3rd**	6	6	
			4.50				3.75				6.00
4th	2	2		**4th**	4	4		**4th**	1		
			2.00				4.00				
5th	1			**5th**	1						
Total	**236**	**176**		**Total**	**437**	**284**		**Total**	**217**	**176**	
Mean value			**3.87**	**Mean value**			**4.33**	**Mean value**			**5.68**

Table 10. Nu, Ndu and Rb values counts for the highest part of the Marecchia River basin and for the Presale and San Marino creeks.

Marecchia	Anomalies number			Anomalous frequences		
	N 1-3	N 1-4	N 1-5	F 1-3	F 1-4	F 1-5
	27	12	6	27	36	42
	N 2-4	N 2-5		F 2-4	F 2-5	
	9	3		18	18	
	N 3-5			F 3-5		
	1			4		
Presale	**Anomalies number**			**Anomalous frequences**		
	N 1-3	N 1-4	N 1-5	F 1-3	F 1-4	F 1-5
	58	48	25	58	144	175
	N 2-4	N 2-5		F 2-4	F 2-5	
	14	4		28	24	
	N 3-5			F 3-5		
	4			16		
San Marino	**Anomalies number**			**Anomalous frequences**		
	N 1-3	N 1-4		F 1-3	F 1-4	
	29	8		29	**24**	
	N 2-4			F 2-4		
	4			8		

Table 11. Anomalies number and anomalous frequencies of the highest part of the Marecchia River basin, and of the Presale and San Marino creeks.

Basins	N_u	N_{du}	A	∑L	D	L	Rf	Rc	Ru	Ra	S
Marecchia	236	176	46.3	141.2	3.05	11.2	0.37	0.61	1.33	0.68	0.60
Presale	437	284	51	181.6	3.56	8.5	0.71	0.84	1.39	0.95	0.41
San Marino	217	176	37.2	100.1	2.69	5.6	1.19	1.09	1.36	1.23	0.46
	P	**F1**	**Rb**	**Rbd**	**R**	**Ga**	**Δa**	**ga**	**log Tu**	**Tu**	**Ta**
Marecchia	32	3.91	3.87	3.15	0.73	145	0.80	3.13	2.47	295.87	0.12
Presale	35.3	6.72	4.33	3.34	0.99	445	1.30	8.73	2.69	493.09	0.20
San Marino	29.5	4.49	5.68	5.13	0.55	61	0.37	1.64	2.34	221.32	0.09

Table 12. Geomorphic quantitative parameters in the highest part of the Marecchia River basin, and in the Presale and San Marino creeks

Recent landforms could not be separated from this northern Apennines sector's geological history. The Apennines are a young and tectonically active mountain chain, having been uplifted above sea level primarily within the Pliocene (Ricci Lucchi F., 1990). 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 & Granger, 2008). Therefore, erosive and denudation stages of the uplifted Apennine mountains have developed during ancient stationing of the local base levels of erosion. The morphogenesis of smooth and low-energy palaeotopographies and/or erosional planation surfaces has been modelled in discordance mainly on the Eocene, Miocene terrigenous units and in the Plio-Quaternary clastic deposits. In the Apennines, the planation surface (PS) by Coltorti & Pieruccini (2000) has levelled all the topographic contrasts. It represents a useful marker for deciphering the Plio-Quaternary evolution of the landscape, allowing us to discriminate between pre- and post-planation tectonic activity. Moreover, it represents a key tool in detecting neotectonic movements and assessing seismic hazard in areas where Plio-Quaternary deposits are not preserved.

The continental morphogenesis, superimposed on the previous one and responsible for the obliteration of the older morphological evolution traces, is testified in the sample sub-basins by the presence of small valleys, large and flared, with hanging riverbeds and, more generally, of a sweet landscape with a weak gradient, currently represented by relict and suspended surfaces at different heights.

The wider remnants are distributed mainly along the watersheds, whereas minor fragments are observable inside the catchment areas. These surfaces, suspended with respect to the current valley floor, are characterised by a surface area that varies from 900 to 87,000 m^2, slopes not exceeding 10° and low energy of relief. These morphological features can be interpreted as flattened surfaces, re-modelled during erosion cycles, whose plano-altimetric distribution of other generations of relict surfaces (between 240 and 1,085 m a.s.l.), is to be correlated to different local base levels. Five orders of palaeosurfaces (S1 to S5) have been distinguished in the sample areas, based on their average height a.s.l. The higher surfaces are relicts of larger erosional surfaces of regional extension (S1). At the same time, those located at lower altitudes present characteristics that seem to indicate modelling more similar to the conditions produced by the current hydrographic network. In many cases, where the erosion processes were highly intense and accelerated, the original paleosurface S1 has been reduced to thin ridges or isolated flat peaks.

These palaeosurfaces can be interpreted as polygenic flattening surfaces, re-modelled during erosion cycles, whose plano-altimetric distribution of other generations of relict surfaces (between 1,350 m and 240 m asl) is to be correlated to different local base levels. The higher surfaces are relicts of larger erosional surfaces of regional extension (S1). At the same time, those located at lower altitudes present characteristics that seem to indicate modelling more similar to the conditions produced by the current hydrographic network. In many cases, where the erosion processes were highly intense and accelerated, the original paleosurface S1 has been reduced to thin ridges or isolated flat peaks (as in Mt. San Marco, Mt. Montone, Mt. Faggiola Nuova or Mt. della Croce).

Erosion, incision, and uplift have existed since the middle Pleistocene, along with the Apennine chain conditioning fluvial dynamics and relative erosional and depositional rate. Many authors have used simple relationships based on quantitative geomorphic analysis methods to estimate river erosion rates with empirical or semi-empirical methods. The application of the Tu index model in the case studies confirms the suitable performance of this approach to predict sediment yield. The values of Tu for the sample basins of Mazzocco, Senatello and Presale rivers are comparable with those calculated on other northern and central Apennine basins with drainage density values in the range 3.6-3.9 (Ciccacci et al., 1988; Della Seta et al., 2009). However, the applied equation does not directly consider factors such as land use, soil erodibility, rainfall erosivity, slope steepness and length, which influence soil erosion processes in the uplands.

Consequently, the outcomes of the equation cannot be directly linked to accelerated soil erosion due to short-term anthropogenic impact. Being based on geomorphologic parameters, this indirect method reasonably expresses the medium-time-scale response of the drainage network to disequilibrium conditions induced by Quaternary climate oscillation and uplift (Della Seta et al., 2009). However, Gioia et al., 2011 suggest that the Tu index can be considered a suitable tool for estimating the medium- to long-term denudation rate in drainage basins characterised by fluvial processes essentially acting in terrigenous deposits as the case studies.

Starting from the Tu value, the erosion rate was calculated using an average value of γs equal to 2.5 gr/cm^3. The erosion rates (Ta) calculated for the intermountain fluvial catchments of Mazzocco, Senatello and Presale are comparable with the erosion rates in the Apennines estimated by Cyr & Granger, 2008 in a variable range from 0.20 to 0.58 mm/yr, from middle Pleistocene (0.9 Myr) to the present day.

Bartolini C., 1999 and Amato et al., 2003 agree that these rates are insufficient to maintain the Apennine in a steady state, although the latter is testified by the presence of V orders of erosional surfaces distributed at different altitudes; the chain uplift is also expressed by the extensive outcrops of marly formations prone to erosion, such as the Marnoso-Arenacea formation, that are found at high elevation and relief energy levels.

Comparing these short-term mean data with the uplift rates calculated on a regional scale (0.41 ± 0.26 mm/yr) in the Marecchia valley (Cyr & Granger, 2008) confirms that the northern Apennines may represent a non-steady state system.

5.4 Geoheritage valorisation

The first considerable impulse to investigate Geoheritage studies was given by the scientific community of Physical Geography and Geomorphology, both in the conservation and tourism sectors. Geomorphology studies landforms, their origin and development, and how they combine to form landscapes and thus Geoheritage.

Since 2001, the Working Group on Geomorphosites within the International Association of Geomorphologists (IAG) started developing a specific field of research on geomorphological heritage within the scientific community (Reynard & Coratza, 2013).

The geomorphological heritage may be considered the landforms worthy of being protected and transmitted to future generations. The geomorphological heritage is presented as part of the Geoheritage, a 'component of the natural heritage' (Reynard et al., 2009). However, this definition now appears to be completed and nuanced, incorporating all the dimensions of the heritage concept (Coratza & Hobléa, 2018).

Heritage is a complex concept, both contested and culturally constructed, depending on personal and collective backgrounds and experiences (Aplin G., 2002). Heritage can also be defined as a transversal concept through time that represents our history, both Man's and Earth's history (Coratza & Hobléa, 2018).

Frequently, heritage is artificially divided into natural and cultural components, but this distinction can sometimes be meaningless and usually blurred. This division is challenging in the case of geomorphological heritage, which comprehends both landforms and processes and relates to the biological and cultural Heritage (Reynard & Coratza, 2016).

Based on these considerations, an innovative conception of geoheritage valorisation has been proposed by the present research, aiming to give an application of this specific kind of heritage to the broader concept of Environmental Education.

This latter has been recognised as of fundamental importance in the last decades, mainly thanks to the numerous initiatives promoted by UNESCO (United Nations Educational Scientific and Cultural Organization). It was declared already almost 50 years ago that a significant change in human behaviour was needed to take more effective action for the global environmental issue (Charter of Statutes of Belgrade, Serbia, 1976[20]). Furthermore, several strategies lead to educational programs that have been conducted to raise awareness of citizens, both towards the needs of the planet and those of the society. The relationship between environmental education and geotourism has been investigated by several studies (Mokhtari et al., 2019; Vegas & Díez-Herrero, 2021; Serrano & González Trueba, 2011), also in their hiking dimension (Ferrera G., 1998), as geoeducation is a component of the broader environmental education field to promote the geological heritage of a place and its conservation. It can be a key tool for tackling environmental issues and assisting in sustainable development (Zafeiropoulos et al., 2021). Nowadays, themes such as geoethics, geodiversity, and geoheritage are not well represented in environmental education, despite the initiatives that have been undertaken at an international level, and their effectiveness is recognised by literature (Tormey D., 2019). It is essential to contribute to spreading geoeducation as a primary tool for transmitting and enhancing places of geological interest for related opportunities of geotourism proposals (Farsani et al., 2011). Geoethics, on the other hand, has become increasingly important as the field that deals with a rational assessment of the geoenvironmental status of the planet and issues connected to geoconservation. Geoethics proposes to improve the social role of geoscience and to increase the sustainable use of natural sources. As a result, it can foster strategies and methods that respect geoheritage (Vascanelos et al., 2015).

For the geotouristic project *Paesaggeo*, digital tools have been implemented to promote and enhance geomorphosites. Still, the central concept under the promotion has been the emotional engagement of the user. In fact, the geological landscape can be considered the bearer of the concept of complexity, expressed in terms of time and space, as the foundation of that sensation of wonder we feel in front of a panorama (Sibi & Valletta, 2014).

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[20] UNESCO U.N. Environment program. In: Proceedings of the International Workshop on Environmental Education at Belgrade, Belgrade, Yugoslavia, 13-22 October 1975; pp. 1-4.

This concept has been investigated through an online survey developed in collaboration with Isabella Ferlini, an ecopsychologist, to understand how a geological landscape is digitally perceived.

Then, a geotourism proposal was performed during summer 2021 to understand how geological landscape is perceived in the first person.

Five geomorphosites (three already existing and two newly proposed) have been the focus of the excursions. Some of them were also selected considering that they had been included in the online survey, allowing to compare the two results.

The data collected over the period from the opening of the Instagram page *Paesaggeo* to the present suggest that themes regarding geology can find a decidedly prolific means of dissemination and exchange in social media. Without using paid tools to disseminate content, such as sponsorships, it was possible to reach interesting goals: with 57 posts, 41 days sharing *stories* and four *reels*, 314 followers were reached, an average of 25 likes and an average of 150 accounts reached per content.

5.4.1 Geological landscape perception: online survey

Emotions play an essential role in people's lives, influencing their thoughts and behaviour. The first psychological studies that explored this link date back to the early 1990s, when Peter Salovey and John Mayer presented the concept of *emotional intelligence* (Salovey & Meyer, 1990), meaning the ability to distinguish and monitor one's own and others' emotions.

In order to survive, each organism must be aware and understand its environment, providing immediate psycho-physical responses to the rapid stimuli coming from outside. It is necessary to be able to discern dangers from what is not, like a prey from hunters; at the same time, one must learn to know the instinctive attitude belonging to one's own species, in order to understand how to control and use emotional instincts (e.g. anger to fight, fear to react or flee). Emotions cannot, therefore, be defined in isolation from the evolutionary context (Plutchik R., 1980).

Ecopsychology, a recent field of psychology, helps understanding why emotions can be relevant in studying landscape perception. In fact, love of nature and a sense of connection with the environment is inherent in human nature, together with the need for the closeness of other living beings, that has its roots in our genetic heritage. Our ancestors lived for millions of years in close contact with the nature that surrounded them, respecting its rhythms and cycles. It is hard to believe that that a few thousand years - a very short period of time in evolutionary terms - were enough to wipe out such a deep-rooted experience (Wilson E.O., 1984).

Restoring a balance in the relationship between man and the natural environment is only possible by including the recognition of the emotions aroused by the observation of the landscape. Be aware of this impact on our lives, on on its quality, can increase our sensitivity to the fragility of territories. This awareness can help us in the prevention of natural risks, because it changes thoughts and therefore actions and habits. New branches of psychology are helping us to give meaning to those sensations that surprise us in front of a landscape, and also allow us to understand and value the impact of landscape on our feelings and emotions[21].

An approach that takes into account feelings, emotions and landscape becomes thus an interesting way of promoting geological culture and highlight the complex interrelationships between the geological landscape and human beings, and Ecopsychology may be of help. This new branch of psichology was born in California at the beginning of the 1990s from the observation of a correlation between the growing existential unease, both at an individual and socialal level, and the increase in environmental damage, in parallel to the rapid process of urbanisation that radically changed the lifestyles and habits of a large part of the world's population. The loss of connection with the natural environment is considered to be a major

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[21] Isabella Ferlini, personal communication, 2020.

cause of psychological distress, and the commitment of ecopsychology is to encourage reconnection with what has been forgotten, or removed by modernisation, in order to integrate the legacy of the past with present goals and future challenges. Ecopsychology finds applications in supporting environmental education and environmentalism to stimulate ecological sensitivity through emotional involvement: as a human species we are part of nature, and our lives depend on the relationship we establish with nature and the environment in which we live (Danon M., 2020). As said by James Hillman, a negative situation we experience may not just be about a depressed mood or an anxious state of mind, but may have something to do with the hermetically sealed buildings in which we work, the dormitory neighbourhood in which we live, or the constantly clogged motorway on which we travel back and forth between the two (Hillman et al., 2005).

Based on these considerations, the online survey has been build by proposing a simple list of emotions which derives from Ekman's studies of emotions (Ekman P., 1992) in order to encourage an initial personal contact with one's most immediate feelings.

Hoping for a deeper awareness in individuals more familiar with recognising their own feelings, it was also proposed to assess the volume of the emotion felt by describing the level of activation (i.e., the arousal) attributed to the emotion. The clusters of emotions proposed are purely indicative and do not intend to make use of criteria peculiar to scientific research,

nor do they intend to be significant for statistical purposes. They should therefore be interpreted as simple self-assessments of subjective and immediate feelings.

For each geological landscape represented in pictures, the users were asked to choose among the following options:

- *Desiderio, speranza (gioia / serenità / interesse)* – Desire, hope (joy/ serenity/ interest);

- *Entusiasmo, ottimismo (amore / gratitudine / libertà / passione)* - Enthusiasm, optimism (love/ gratitude/ freedom/ passion);

- *Noia (indifferenza / distacco)* - Boredom (indifference/ detachment);

- *Nostalgia (malinconia / rassegnazione / delusione)* - Nostalgia (melancholy/ resignation/ disappointment);

- *Preoccupazione, timore (ansia / tristezza / frustrazione / sopraffazione)* - Worry, concern (anxiety/ sadness/ frustration/ overwhelm);

- *Dolore, rabbia (fastidio / paura / impotenza)* - Pain, anger (discomfort/ fear/ helplessness).

The other question asked for each picture is "Would you like to see it live?", with "Yes", "No", and "I'm not sure" as possible answers (Figure 59).

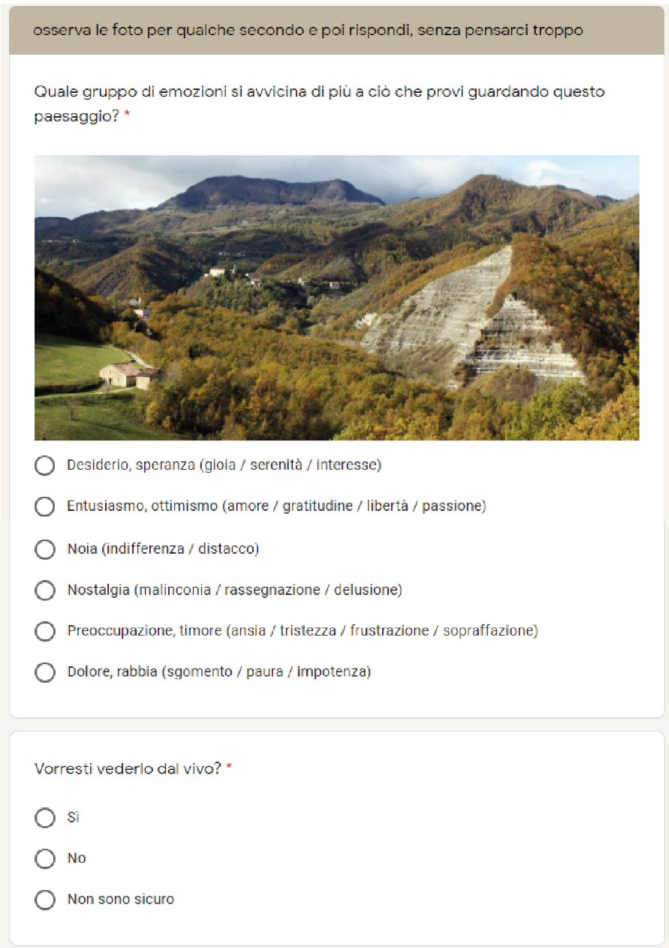


Figure 59. *Paesaggeo* online survey.

At the end of the survey, very general information is asked to the user to have a basic knowledge of the people who are sensitive to these topics (age and origin).

It is worth noticing that promoting the online survey through Instagram only (from April to December 2021) led to a total of 31 answers. Most of the answers were obtained after sending the poll personally to all people who took part in the summer excursions, to friends and colleagues, until reaching a total of 165 responses.

To compare results from the different geological landscapes, four groups have been identified:

- warm-coloured geological landscapes: Casteldelci cliff; Colorìo marls; Sasso Simone cliff; Tausano rock-fall; Mt. Pincio and Aquilone (Figure 60);
- cold-coloured geological landscapes: honeycomb erosion of Mt. Perticara; San Leo and the Tausani cliff; Maiolo cliff and badlands; Costa dello Speco and Marecchia River; Pratieghi marls (Figure 61);
- landslides: small landslide with a tree; active rock-fall of Maiolo; moving boulders of Sasso Simone (Figure 62);
- quarry sites: San Giovanni in Galilea quarry; Mt. Ceti quarry (Figure 63).

Figure 60. Warm-coloured landscapes of *Paesaggeo* online survey.

Figure 61. Cold-coloured landscapes of *Paesaggeo* online survey.

Figure 62. Landslides of *Paesaggeo* online survey.

Figure 63. Quarry sites landscapes of *Paesaggeo* online survey.

The results are presented here in a merged mode, obtained by summing and putting into percentage the results obtained for each group.

1. Warm-coloured geological landscapes produce the highest positive activations in users, with 80.61%. Deactivation reaches 12.12%, while negative activation is equal to 7.27%. 91.06% of the users would like to see those kinds of geological landscapes, 4.39% of users declare they don't want to, 4.55% said they don't know.

2. Cold-coloured geological landscapes have a slightly lower percentage of positive activations, with a 72.49%. Deactivation increased to 16.36%, and negative activation was perceived by 11.15% of the compilers. 84.12% of the users would like to see these geological landscapes live, 7.27% wouldn't, and 8.61% don't know.

3. The images picturing landslides obtained a 47.68% of positive activations in users, 18.38% cases of deactivations and 33.94% of negative activation. Nevertheless, 74.34% of compilers declared that they would like to see that geological landscape live, 15.15% don't want to, while 10.51% don't know.

4. Quarry sites are the most negatively perceived geological landforms in the survey. They gave 43.64% of negative activations, a 25.76% of deactivations and just a 30.6% of positive activations. 60.3% of users would however like to see them live, 27.88% said they don't, 11.82% said they don't know.

5.4.2 Dissemination of geomorphological values through live experiences

As our daily lives are littered with pervasive and sometimes invasive technologies, the importance of experiencing nature at first hand seems more relevant than ever. It is expressed as a renewed interest on the part of people to live in closer contact with the natural environment. This is why it was decided to experiment with disseminating geomorphological heritage concepts through a series of dedicated events. They took place on weekends from May to August 2021 as follows:

- May, Saturday 29 and Sunday 30: Sasso Simone and Simoncello geomorphosite;
- June, Saturday 26 and Sunday 27: Mt. Ercole and Mt. San Silvestro geomorphosite;
- July, Saturday 24 and Sunday 25: Maiolo cliff and badlands geomorphosite;
- August, Saturday 28 and Sunday 29: Maciano hill and Scavolino palaeo-lake geomorphosites.

On Saturdays, the "Exploratory" mode was proposed in the mornings and early afternoons, while the "Immersive" mode took place in the later afternoon and evening. On Sundays, the mornings and early afternoons were dedicated to the "Test" mode and the later afternoons and evenings to the "Artistic" mode. Mealtimes were included in all the excursions, to allow the group to have a moment of sharing, relaxation and confrontation both within the group and with the guide and the other accompanying persons.

At the beginning of each experience, the participants were given a general context of the research, with the definitions of geosites, geomorphosites and geological heritage. They were also asked at the beginning or at the end of each appointment the possibility to send an evaluation survey concerning the emotional involvement experienced during the excursion and some other contents of the research.

The types of experience have been designed to be emotionally engaging at different levels and conducted as closely as possible to the following principles:

1. *Escursione nel Paesaggeo* - "Test" mode, i.e., a classic excursion in nature trails, accompanied by an environmental guide who explains the salient geological features of the various landscapes, using scientific terms accompanied by explanations and examples, and accompanying users in reading the landscape with descriptions in words (Figure 64).

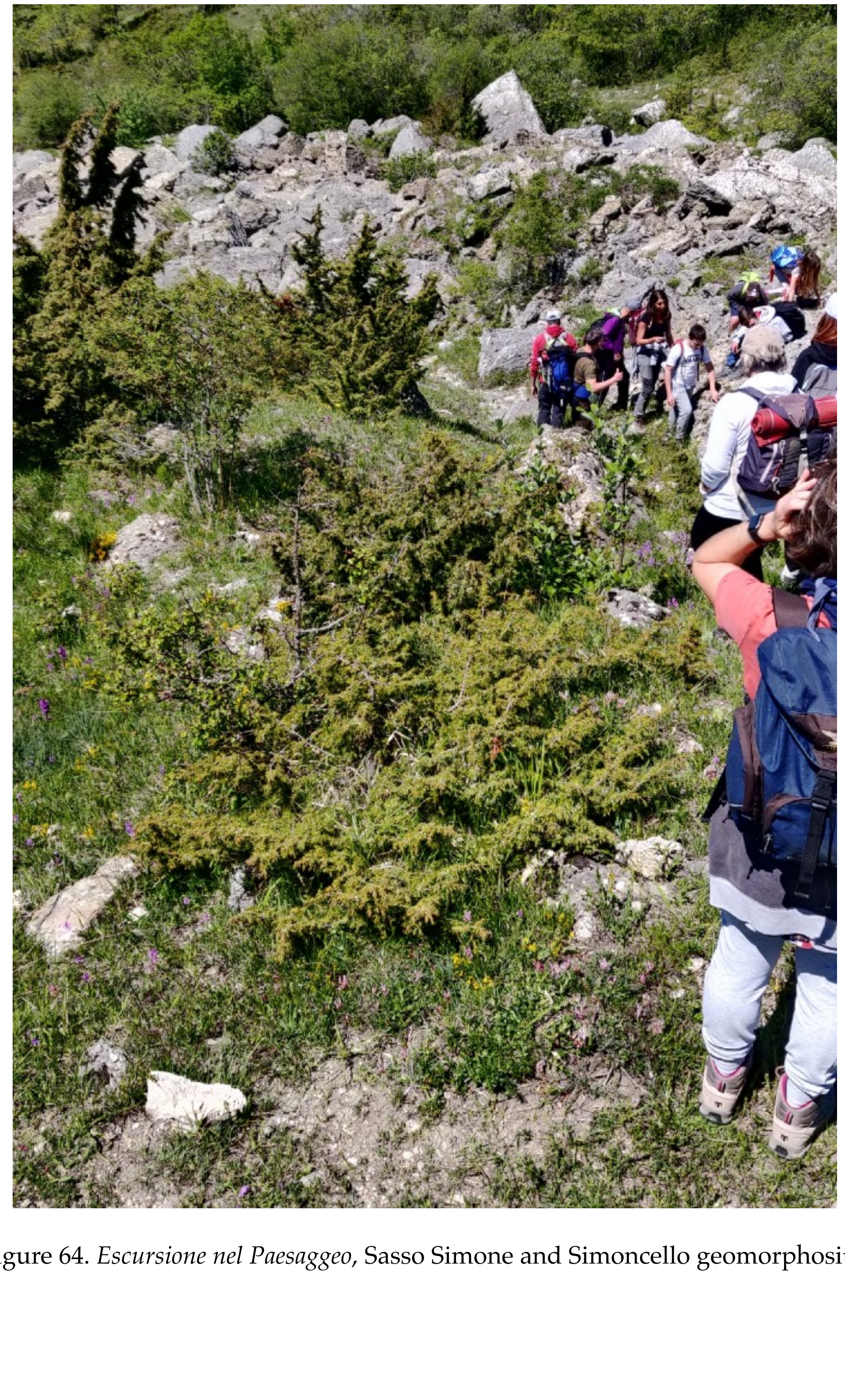


Figure 64. *Escursione nel Paesaggeo*, Sasso Simone and Simoncello geomorphosite.

2. *Esploriamo un Paesaggeo* - "Exploratory" mode, in which the environmental guide brings users out of the main trails to find geological treasures and hidden processes into the wildest areas. Users are asked to put themselves to the test on a physical level, each according to their aptitudes, but invited to curiosity and exploration, research, touch by hand, and put their trekking boots directly on the geological heritage (Figure 65).

Figure 65. *Esploriamo un Paesaggeo*, Maiolo cliff and badlands geomorphosite.

3. *Una storia nel Paesaggeo* - "Immersive" mode, carried out in collaboration with the informal collective Malafeltro, in which gamification dynamics characterise the experiences conceived to enhance the geological and cultural heritage. This modality can be described as a sort of time travel, through which the user finds himself living a story in first person, set in climatic and historical-cultural contexts of the past, surrounded by characters dressed up accordingly to the period of the narration. Participants are called upon to interact with the story on several levels, through the characters or objects in the natural scenery and to use their imagination to recreate past natural settings around them. The characters involve the audience with techniques typical of theatrical improvisation and stimulate their imagination with evocative language (Figure 66).

Figure 66. *Una storia nel Paesaggeo*, Sasso Simone and Simoncello geomorphosite.

4. *Ascoltiamo un Paesaggeo* - "Artistic" mode, which expresses the geological heritage through the languages of poetry and music. This method is confirmed by various experiences (Nesci & Valentini, 2015, 2016, 2020; Valentini & Nesci, 2021) already experimented by the group of scientists and artists of *TerreRare*, actively involved in elaborating this particular proposal. As far as the language of poetry is concerned, it was decided to use existing verses, inspired by the vision of the geological landscapes as the destination of the dedicated excursions, or composed precisely for them, as in the specific case of Sasso Simone. Where available, prose

testimonies or local chronicles related to the geological events involved in the excursion were also read. In addition to the readings, each tour included a moment dedicated to an acoustic piece of music performed live in suggestive settings, at evocative times. The pieces were composed by Lorenzo Brighi, a young musician and goat farmer living in the Marecchia Valley passionate about nature and landscapes. After a preliminary excursion to each selected site, in which the geological aspects were explained to him in detail, Lorenzo elaborated four particular melodies, which were then rearranged for the public event. The pieces are to be understood as the author's artistic transposition, the result of his specific sensitivity and are a direct derivation of his experience of the geological heritage (Figure 67).

Figure 67. *Ascoltiamo un Paesaggeo*, Sasso Simone and Simoncello geomorphosite.

The results from the survey, which has been compiled by 85 people who participated in the various proposals, are hereafter reported, offering a panoramic view of the live part of the project *Paesaggeo*. The first four questions aim to obtain the user's general opinion about geosites and hiking experiences able to enhance them. The collected answers make clear how positive the perception of geological heritage and geologically themes treks has been

in the groups, and how this kind of experience triggers a curiosity to make similar ones in the future.

1. Q: Do you think it is important to enhance sites of geological interest through geologically themed excursions?

A: Yes - 100% (85/85)

A: No - 0% (0/85)

2. Q: Do you think that this particular site of geological interest should be enhanced through geologically themed excursions?

A: Yes - 98.82% (84/85)

A: No - 1.18% (1/85; Maciano hill and Scavolino Palaeo-lake)

3. Q: Had you ever participated in a geologically themed hike, led by a hiking guide specialised in geology?

A: Yes - 49.41% (42/85)

A: No - 50.59% (43/85)

4. Q: After this experience, do you think you will participate in other geological excursions in the future?

A: Yes - 100% (85/85)

A: No - 0% (0/85)

Question number 5 is about which type of excursion did the users participate in, and the answers report how events involving other accompanying figures (i.e., Malafeltro collective or the guitarist), and reflecting a highly interdisciplinary approach, were able to reach more people.

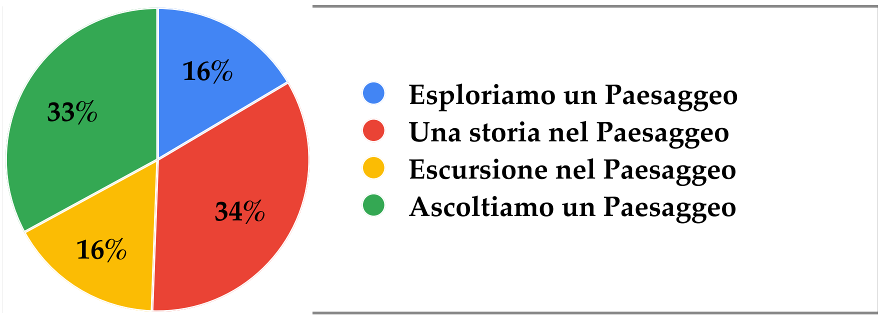
5. Q: What kind of event did you take part in?

A: *Esploriamo un Paesaggeo* (Let's explore a Geological landscape) - 16.47% (14/85)

A: *Una storia nel Paesaggeo* (A story in the Geological landscape) - 34.12% (29/85)

A: *Escursione nel Paesaggeo* (Trekking in a Geological landscape) - 16.47% (14/85)

A: *Ascoltiamo il Paesaggeo* (Let's listen to the Geological landscape) - 32.94 (28/85)



Question number 6 is aimed to understand if the different types of treks are able to transmit the geological values of the selected geomorphosites, and the answers show how all the participants felt like the mode they chose to participate in can be considered effective in transmitting those values.

6. Q: Do you feel that the trek mode in which you participated was effective in conveying the geological values and content of these places?

A: Yes - 100% (85/85)

A: No - 0% (0/85)

Question number 7 is the first concerning emotional engagement and enables to compare the results of the different tested approaches.

7. Q: How emotionally involved were you during the excursion? (scale from 1 to 5)

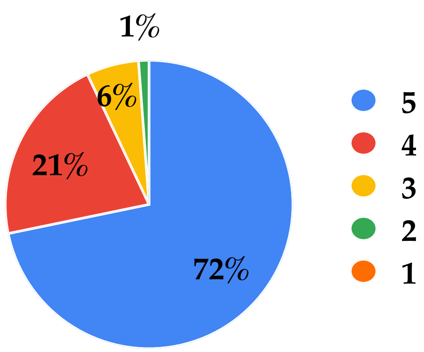
A: 5 - 71.76% (61/85)

A: 4 - 21.18% (18/85)

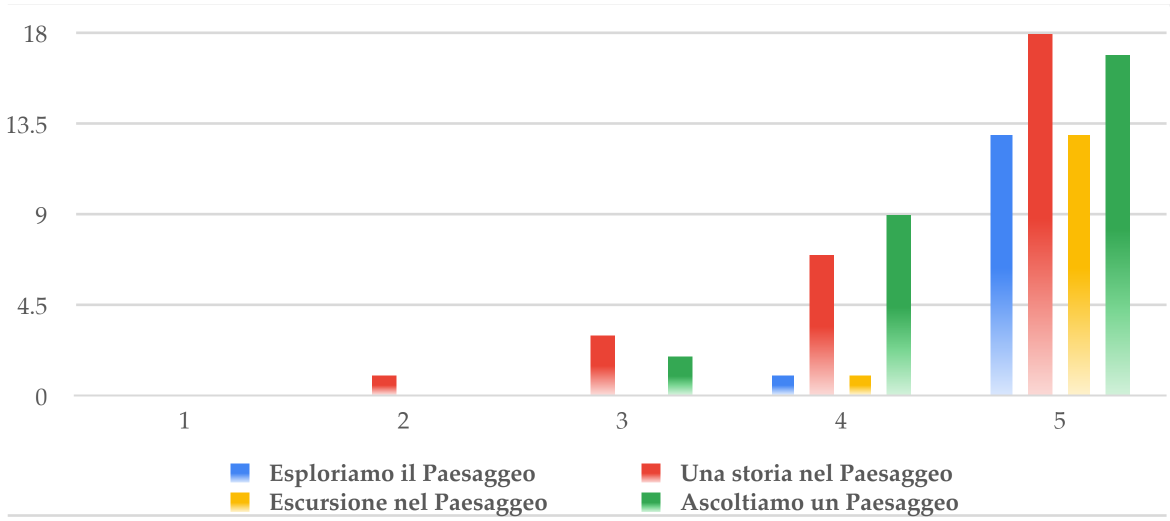
A: 3 - 5.88% (5/85)

A: 2 - 1.18% (1/85)

A: 1 - 0% (0/85)



Referring to the different approaches, the following graph enhance how there are no detectable fundamental differences between the tested modes. This may be explained as a consequence of the natural power of emotional engagement provided naturally by spectacular geological landscapes, or the excitement of living experiences in nature, in groups, in the first person.



Question number 8 is aimed to ask the participants' opinion about the dissemination of geological concepts with emotional engagement and shows how it could be an innovative tool resulting in more effective communication and enhancement of geological heritage.

8. Q: Do you think that a way of enjoyment of the territory that includes emotional engagement can be effective in transmitting geological content?

A: Yes - 98.82% (84/85)

A: No - 1.18% (1/85)

Question number 9 is aimed to understand if the proposed unusual kinds of geologically themed treks have been able to interest and build the users' loyalty to these kind of projects, resulting in a positive answer.

9. Q: Would you be curious to try the other excursion modes?

A: Yes - 98.82% (84/85)

A: No - 1.18% (1/85; *Escursione nel Paesaggeo*)

Questions number 10 and 11 are aimed to collect basic information about the users' (their age and origin). The sample group was found to be composed of mainly the last two sectors of age, but also with a strong presence of underage users. The provenance was mainly from Valmarecchia and Montefeltro areas, or the neighbouring areas. This expresses the involvement mainly of locals, inhabitants and not tourists, probably reflecting the catchment areas of the excursion proposals of Natural Park Sasso Simone and Simoncello.

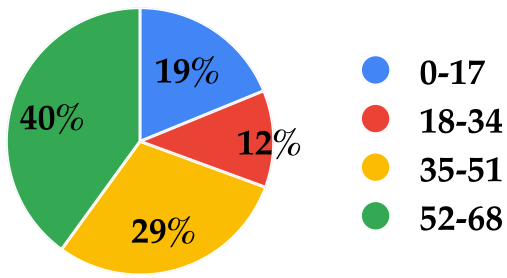
10. Q: How old are you?

A: 0-17 - 18.82% (16/85)

A: 18-34 - 11.76% (10/85)

A: 35-51 - 29.41% (25/85)

A: 52-68 - 40% (34/85)



11. Q: Where do you live?

A: Valmarecchia e Montefeltro - 24.71% (21/85)

A: San Marino - 12.94% (11/85)

A: Emilia Romagna / Marche / Toscana - 55.29% (47/85)

A: Italia - 7.06% (6/85)

Question number 12 is aimed to get to know how the users' came in contact with the geotouristic offer of the *Paesaggeo* project. The results show how word-of-mouth (i.e., *passaparola*) can still be one of the best methods for communication, slightly more effective than Facebook and Instagram pages of Natural Park of Sasso Simone and Simoncello combined. Also, direct invitations from the hiking guide have resulted in a high number of participants, proving how user loyalty is crucial in the promotion of nature-based experiences. Finally, only a few contacts took place thanks to *Paesaggeo* Instagram profile. The primary digital sources of dissemination aimed at participating in the events were mainly the newsletter and the Facebook and Instagram pages of the Natural Park of Sasso Simone and Simoncello. Posts dedicated to *Paesaggeo* experiences had in fact an average coverage of 2,000 people, enhancing how the affiliation with the excursion program of the Park was fundamental in promoting a newborn project, which couldn't be able to reach such a trusted public.

12. Q: How did you find out about the project?

A: Word-of-mouth - 35.29% (30/85)

A: Natural Park Sasso Simone and Simoncello Facebook or Instagram profiles - 29.41% (25/85)

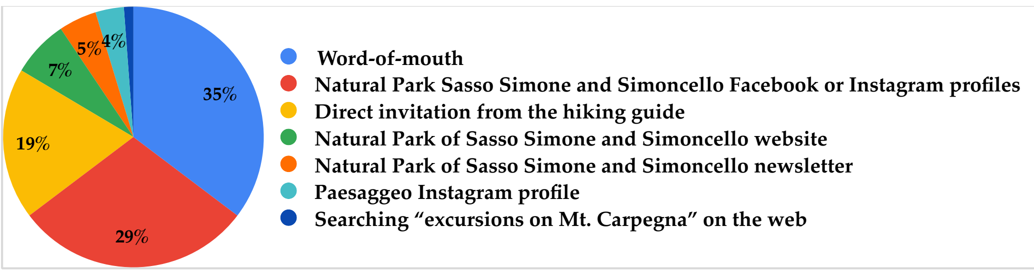
A: Direct invitation from the hiking guide - 18.82% (16/85)

A: Natural Park of Sasso Simone and Simoncello website - 7.06% (6/85)

A: Natural Park of Sasso Simone and Simoncello newsletter - 4.71% (4/85)

A: Paesaggeo Instagram profile - 3.53% (3/85)

A: Searching "excursions on Mt. Carpegna" on the web - 1.18% (1/85)



Lastly, an open question is asked to the users, regarding comments or suggestions for the project. Many of the comments show a sincere appreciation and the hope that similar projects could be proposed in the future. Here are reported those expressing interesting aspects, also with the indication of the age of the compiler and kind of the excursion.

- "The excursion was very enjoyable, especially thanks to the kindness and availability of the guide, who did not miss any opportunity to answer all the participants' curiosities, even outside the theme of the day, which she explained with skill and expertise. The very small size of the group made it easy for everyone to get to know each other, thus creating a very familiar atmosphere" (18-34; *Esploriamo un Paesaggeo*);
- "Provide before or after a written contribution and/or in-depth links" (52-68; *Esploriamo un Paesaggeo*);
- "The only advice I can give is to try to involve the very young as much as possible. I find it a very educational experience, and not just from a geological point of view" (52-68; *Esploriamo un Paesaggeo*);
- "Interesting and well organised. The guide also showed knowledge on several integrated themes, such as flora, fauna, human and social aspects of the places crossed during the excursion" (52-68; Esploriamo un Paesaggeo);
- "Try to have groups with horizontal characteristics (by age, same training, etc.)" (52-68; *Esploriamo un Paesaggeo*);
- "It was beautiful! I will always remember the lakes of Scavolino!" (0-17; Una storia nel Paesaggeo);
- "We understood and experienced the events in Maioletto almost directly. The place has now acquired a meaning for us that could never have been conveyed by a simple explanation. I hope that this kind of initiative will not be abandoned" (52-68; *Una storia nel Paesaggeo*);

- “The emotional involvement was very strong. The excellent idea and the enthusiasm motivating the organisers managed to create a magical moment. The place - where I had never been before - is now one of my places” (52-68; *Una storia nel Paesaggeo*);
- “The different ways of approaching the history and geology of the area are winning. This one in particular saw the guide act as an actress in a performance that emotionally involved all the participants. The choice of comedians, plot, clothes and objects; the search for spontaneous herbs and what in nature produces sounds; the speeches always relating to the event of the landslide and the anguish of the survivors made sure that a leap back in time really happened. Well done!” (52-68; *Una storia nel Paesaggeo*);
- “I would like events of this kind to be held on a regular basis. The idea of combining history/geology is very original and worth more than many books read and half-forgotten…” (52-68; *Una storia nel Paesaggeo*);
- “Propose it to schools. If the new generations were involved it would preserve the territory by transmitting history, values and respect for the environment” (52-68; *Una storia nel Paesaggeo*);
- “I found the portrayal of the historical figures very credible and indispensable, both to get participants into the spirit of the time and to relive the landscape, which became palpable and real even if imagined. In my visual memory, I can still "see" the lakes of Scavolino, places I had already visited but had not memorised so clearly. I have no advice other than to continue with this immersive, playful, emotionally and cognitively involving approach” (52-68; *Una storia nel Paesaggeo*);
- “I would like to spend the whole day in the badlands looking for stones and minerals” (0-17; *Escursione nel Paesaggeo*);

- "I would do activities that have to do with geology but are not necessarily explanatory: e.g. 1) thematic games, 2) group research" (0-17; *Ascoltiamo un Paesaggeo*);
- "Very nice poetic and musical moment. Perhaps I would enrich this event with more such moments during the walk" (18-34; *Ascoltiamo un Paesaggeo*);
- "It would be nice to have emotional moments also during the route and not only at the end in order to experience the emotions while seeing the places" (18-34; *Ascoltiamo un Paesaggeo*);
- "I really enjoyed the combination of walking, music, poetry, nature, history, curiosity. Added values were the guide's passion and love for the area and the topics she spoke about" (35-51; *Ascoltiamo un Paesaggeo*);
- "The dissemination of scientific content through art is an effective strategy that should be strengthened!" (35-51; *Ascoltiamo un Paesaggeo*);
- "With the help of an experienced and knowledgeable guide, I became aware of the morphological fragility of our territory" (52-68; *Ascoltiamo un Paesaggeo*);
- "The expert, professional and motivated leadership of the guide, the reading of a story and a poem, the opportunity to listen to unpublished pieces by a shepherd guitarist and musician, the choice of route and location for the dinner, the educated and sensitive participants to the wonders of nature made this experience a moment to remember" (52-68; *Ascoltiamo un Paesaggeo*).

5.4.3 Is live experiences worth it?

The comparison between the online survey and the one submitted to the participants of the excursions has evidenced how the geological landscape can be perceived differently in relation to the two modalities. In fact, a live view of geological features produce feelings positively different from those triggered by a digital image of the same landscape.

Two of the geomorphosites selected for the geotourism proposal (Sasso Simone and Simoncello and Maiolo cliff and badlands) were portrayed in pictures of the digital perception survey, in a number of two for each site. The same question about perception has thus been asked to the users who participated in the geologically themed treks.

The results of the comparison between the two modalities evidence how, in all cases, the online perception counts a more significant number of negative activations or deactivation of users, while the live view results in conveying positive emotions and results in positive activation of users.

1. The live view of Maiolo badlands has resulted in a complete zeroing of the negative activations (from 21.21% to 0%), deactivation goes from 16.36% to 5.56%, while positive activation goes up from 62.43% to a striking 94.44%.

2. The live view of the southern cliff of Sasso Simone and Simoncello has resulted in an increase in positive activation responses (from 79.39% to 91.67%), deactivation in users passed from 7.88% in the online survey to 4.16% in the live experience. Negative activation passed from 12.73% in the online survey to 4.16% in the users who experienced a live view of the cliff.

3. The view of the active rock-fall of Maiolo has resulted in a 69.09% of positive activations online, which went to an 88.88% in the case of a live view. Negative activation was reduced from 20.61% of the online view to 5.56% of the live view and deactivation passed from 10.3% to 5.56%.

4. The view of the peculiar boulders moving from the cliff of Sasso Simone going south has been positively perceived by 87.5% of users in the case of a live view, while the online survey obtained a 56.36% of positive activation in users. Deactivation goes from 26.06% of the online view to 12.5% of the live view, and negative activation has decreased from 17.58% of the online survey to 0% in the live view.

From these results, it can be assumed that a live view of the geological heritage can result in a general more positive perception from non-experts, which can be increased even more if the portrayed phenomena are accompanied by explanations of hiking guides or a positive involvement at an emotional level.

CHAPTER 6.
CONCLUSIONS

This doctorate research has managed to obtain consistent and unpublished scientific data on the whole territory of Valmarecchia, with the production of two thematic maps (a simplified geological map and a geomorphological map) and a digital atlas aimed to promote and enhance the geoheritage of the Marecchia valley.

The basic geomorphological knowledge has been integrated with quantitative geomorphic analyses and quantitative assessment of geosites. They have been applied to become the foundation for an integrated geotourism offer at the basin level. Local authorities or privates can use this knowledge to implement services in these territories.

Moreover, the experimentation of innovative methodologies has enabled to reach a broad public, enhancing the geological and geomorphological heritage without any distinction based on social origin and age.

Finally, another collateral strength of this research is that the effectiveness of geological dissemination through experiences carried out by specialised Environmental Hiking Guides has been proven.

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References

Amato A., Aucelli P.P.C., Cinque A. (2003). The long-term denudation rate in the Southern Apennines Chain (Italy): A GIS-aided estimation of the rock volumes eroded since middle Pleistocene time. Quat. Int., 101, pp. 3–11.
https://doi.org/10.1016/S1040-6182(02)00087-3

Antoniazzi A., Galassini E., Milliken S., Peretto C., Piani G. (1998). Lower Palaeolithic industries of the Castelbolognese area, Atti del XIII Congresso UISPP, Workshop 13, vol. 6, tomo 2, pp. 969–979.

Aplin G. (2002). Heritage identification, conservation and management. Oxford Univerisy press, Victoria.

Argnani A. & Ricci Lucchi F. (2001). Tertiary silicoclastic turbidite systems of the Northern Apennines. In G. B. Vai & I. P. Martini (Eds.), Anatomy of an Orogen: The Apennines and adjacent Mediterranean basins, Dordrecht: Kluwer Academic, pp. 327–350. https://doi.org/10.1007/978-94-015-9829-3_19

Arzarello M. & Peretto C. (2010). Out of Africa: The first evidence of Italian peninsula occupation. Quaternary International, 223-224, pp. 65–70.
https://doi.org/10.1016/j.quaint.2010.01.006

Avena G.C., Giuliano G., Palmieri E.L. (1967). Sulla valutazione quantitativa della gerarchizzazione ed evoluzione dei reticoli fluviali. Boll. Soc. Geol. It., 86, pp. 781–796.

Bartolini C. (1999). An overview of Pliocene to present-day uplift and denudation rates in the Northern Apennine. Geol. Soc. London Spec. Publ. 1999, 162, pp. 119–125.
https://doi.org/10.1144/GSL.SP.1999.162.01.10

Bastiani M. (2011). Contratti di fiume pianificazione strategica e partecipata dei bacini idrografici. Approcciesperienze - casi studio, Palermo, Dario Flaccovio Editore.

Battistini C., Battistini M. (2011). Le strutture rupestri della Valmarecchia. In Moroni Lanfredini A. and Laurenzi G.. Pietralba, indagine multidisciplinare su alcuni manufatti rupestri dell'Alta Valtiberina, pp. 114-127.

Bebi P., Delucca O. (1994). Le grotte di Santarcangelo nei documenti d'archivio, in Le grotte di Santarcangelo. (Atti della giornata di studi. Santarcangelo, 1988), Cesena, Società di Studi Romagnoli, pp. 59-88.

Benedetti G., Bernardi M., Bonaga G., Borgatti L., Continelli F., Ghirotti M., Guerra C., Landuzzi A., Lucente C.C., Marchi G. (2013). San Leo: centuries of coexistence with landslides. In Margottini C., Canuti P., Sassa K. (Eds): Landslide Science and Practice, 6 (Risk Assessment, Management and Mitigation), pp. 529-537. https://doi.org/10.1007/978-3-642-31319-6_69

Bollati M.I., Lenz B. C., Zanoletti E., Pelfini M. (2017). Geomorphological mapping for the valorization of the alpine environment. A methodological proposal tested in the Loana Valley (Sesia Val Grande Geopark, Western Italian Alps). Journal of Mountain Science, 14(6), pp. 1023-1038. https://doi.org/10.1007/s11629-017-4427-7

Bollati M.I., Coratza P., Giardino M., Panizza V., Pelfini, M. (2018). I Geomorfositi. In: Campobasso C., Carton A., Chelli A., D'Orefice M., Dramis F., Graciotti, R. Aggiornamento ed integrazioni delle Linee guida della Carta geomorfologica d'Italia alla scala 1: 50.000. Quaderni serie III.

Bonachea J., Bruschi V.M., Remondo J., González-Díez A., Salas L., Bertens J., Cendrero A., Otero C., Giusti C., Fabbri A., González-Lastra J.R., Aramburu J.M. (2005). An approach for the incorporation of geomorphologic factors into EIA of transportation infrastructures: a case study in northern Spain. Geomorphology 66, pp. 95–117. https://doi.org/10.1016/j.geomorph.2004.09.008

Bonarelli, G. (1929). Interpretazione strutturale della regione feltresca. Boll. Soc. Geol. It., 48, pp. 314-316.

Bonciani F., Cornamusini G., Callegari I., Conti P., Foresi L.M. (2007). The role of the "Coltre della Val Marecchia" within the tectonic-sedimentary evolution of the Romagnan-Marchean Apennines. Rend. Soc. Geol. It., 83, pp. 155-190.

Borchia R. & Nesci O. (2012). The invisible landscape. A fascinating hunt for the real landscapes of Piero della Francesca among Montefeltro Hills. Il Lavoro Editoriale (Eds.), Ancona, Italy. 144 p.

Borchia R. & Nesci O. (2021). Montefeltro paesaggio rinascimentale. Ebook available at https://assets.montefeltroartviews.it/choose-ebook/books/ebook_it_low.pdf

Bouzekraoui H., Barakat A., El Youssi M., Touhami F., Mouaddine A., Hafid A., Zwoliński Z. (2018). Mapping Geosites as Gateways to the Geotourism management in Central High-Atlas (Morocco). Quaestiones Geographicae, 37 (1), pp. 87-102. https://doi.org/10.2478/quageo-2018-0007

Bouzekraoui H., Barakat A., Touhami F., Mouaddine A., El Youssi, M. (2018). Inventory and assessment of geomorphosites for geotourism development: A case study of Aït Bou Oulli valley (Central High−Atlas, Morocco). Area, 50(3), pp. 331-343. https://doi.org/10.1111/area.12380

Brilha J. (2015). Inventory and quantitative assessment of geosites and geodiversity sites. Geoheritage. https://doi.org/10.1007/s12371-014-0139-3

Bruno D.E., Crowley B.E., Gutak Ja.M., Moroni A., Nazarenko O.V., Oheim K.B., Ruban D.A., Tiess G., Zorina S.O. (2014). Paleogeography as geological heritage. developing geosite classification. Earth-Science Reviews, 138, pp. 300–312. https://doi.org/10.1016/j.earscirev.2014.06.005

Campobasso C., Carton A., Chelli A., D'Orefice M., Dramis F., Graciotti R. (2018). Aggiornamento ed integrazioni delle Linee guida della Carta geomorfologica d'Italia alla scala 1: 50.000. Quaderni serie III.

Cantalamessa G., Centamore E., Chiocchini U., Micarelli A., Potetti M. (1986). Il Miocene delle Marche. Studi Geologici Camerti, Volume speciale "La geologia delle Marche" (0), pp. 35–55.

Capozzi, R., Landuzzi, A., Negri, A., Vai, G. (1991). Stili deformativi ed evoluzione tettonica della successione neogenica romagnola. Stud. Geol. Camer., 1, pp. 261–278.

Carbone R., Fortunato G., Pace G., Pastore E., Pietragalla L., Postiglione L., & Scorza F. (2018). Using open data and open tools in defining strategies for the enhancement of Basilicata Region. In *International Conference on Computational Science and Its Applications*. Springer, Cham., pp. 725-733. https://doi.org/10.1007/978-3-319-95174-4_55

Carmignani L., Conti P., Cornamusini G., Meccheri M. (2004). The internal Northern Apennines, the Northern Tyrrhenian Sea and the Sardinia-Corsica Block. In Geology of Italy. Special Volume of the Italian Geological Society for the IGC Florence; Crescenti, S.U., D'Offizi, S., Merlino Sacchi, L., Eds.; Società Geologica Italiana, Roma: Rome, Italy; pp. 59–77.

Carmignani L., Conti P., Cornamusini G., Pirro A. (2013). Geological map of Tuscany (Italy). J. Maps 2013, 9, pp. 487–497. https://doi.org/10.1080/17445647.2013.820154

Carton A., Coratza P. Marchetti M. (2005). Guidelines for geomorphological sites mapping: examples from Italy. Géomorphologie: relief, Processus, environnement, 3, pp. 209-218. https://doi.org/10.4000/geomorphologie.374

Casagli N. (1994). Meccanismi di Instabilità iIndotti dal Contrasto di Competenza in Ammassi Rocciosi su un Substrato Deformabile. Ph.D. Thesis, University of Milan, Milan, Italy.

Centamore E., Chiocchini U., Cipriani N., Deian, G., & Micarelli A. (1978). Analisi dell'evoluzione tettonico- sedimentaria dei "Bacini Minori" torbiditici del Miocene Medio-Superiore nell'Appennino umbro-marchigiano e laziale-abruzzese. Memorie della Società Geologica Italiana, 18, pp. 135–170.

Cerrina Feroni A., Ghiselli F., Leoni L., Martelli L., Martinelli P., Ottria G., Sarti G. (1997). L'assenza delle Liguridi nell'Appennino romagnolo: relazioni tra il sollevamento quaternario e implicazioni strutturali. Il Quaternario, 10, pp. 371–376.

Cerrina Feroni A., Ottria G., Martinelli P., Martelli L. (2002). Carta Geologico-Strutturale dell'Appennino Emiliano-Romagnolo. Scala 1:250.000, Regione Emilia-Romagna; Consiglio Nazionale delle Ricerche: Bologna, Italy.

Cesarini R. (2013). Analisi geomorfologica e storica dell'area circostante il paleolago di Scavolino (bacino del fiume Marecchia). Dissertation thesis. University of Urbino "Carlo Bo".

Ciccacci S., D'Alessandro L., Fredi P., Lupia Palmieri E. (1988). Contributo dell'analisi geomorfica quantitativa allo studio dei processi di denudazione nel bacino idrografico del Torrente Paglia (Toscana meridionale–Lazio settentrionale). Geogr. Fis. Din. Quat., 1, pp. 171–188.

Ciccacci S., Fredi P., Palmieri E.L., Pugliese F. (1980). Contributo dell'analisi geomorfica quantitativa alla valutazione dell'entità dell'erosione nei bacini fluviali. Boll. Soc. Geol. It., 99, pp. 455–516.

Ciccacci S., Fredi P., Palmieri E.L., Pugliese F. (1986). Indirect evaluation of erosion entity in drainage basins through geomorphic, climatic and hydrological parameters. Int. Geomorphol., 2, pp. 33–48.

Ciccacci S., Fredi P., Lupia Palmieri E. (1979). Quantitative expression of climatic and geomorphic factors affecting erosional processes: Indirect determination of the amount of erosion in drainage basins in Italy. An approach. In Proceedings of the Polish-Italian Seminar "Superficial Mass Movement in Mountain Regions", Warszawa, Poland, pp. 76–89.

Clementini C. (1617). Raccolto Istorico della fondatione di Rimino e dell'origine, e vite de' Malatesti: con vari, e notabili fatti en essa Città, e fuori di tempo in tempo successi. Vol. I 1617, Vol. II, 1627.

Coltorti M. (1991). Modificazioni morfologiche oloceniche nelle piane alluvionali marchigiane: alcuni esempi nei fiumi Misa, Cesano e Musone. Geogr. Fis. Din. Quat., 14, pp. 73–86. https://doi.org/10.1016/0167-9317(91)90155-7

Coltorti M., Pieruccini P. (2000). A late Lower Pliocene planation surface across the Italian Peninsula: A key tool in neotectonic studies. J. Geodyn., 29, pp. 323–328. https://doi.org/10.1016/S0264-3707(99)00049-6

Comănescu L., Nedelea R., Dobre R. (2012). The evaluation of geomorphosites from the Ponoare Protected Area. Forum geografic. Studii s i cercetări de geografie s i protect ia mediului 11(1), pp. 54–61. https://doi.org/10.5775/fg.2067-4635.2012.037.i

Comănescu L., Nedelea A., Dobre R. (2013). The geotouristic map-between theory and practical use. Case study-the central sector of the Bucegi Mountains (Romania). Geo-Journal of Tourism and Geosites, 11, pp. 16-22.

Comănescu L., Nedelea A., Stănoiu G. (2017). Geomorphosites and geotourism in Bucharest city center (Romania). Quaestiones Geographicae, 36 (3), pp. 51-61. https://doi.org/10.1515/quageo-2017-0029

Conti, P., Cornamusini, G., & Carmignani, L. (2020). An outline of the geology of the Northern Apennines (Italy), with geological map at 1: 250,000 scale. Italian Journal of Geosciences, 139(2), 149-194. https://doi.org/10.3301/IJG.2019.25

Conti S., Fregni P., Gelmin R (1987). L'età della messa in posto della coltre della Val Marecchia. Implicazioni paleogeografiche e strutturali. Mem. Soc. Geol. It., 39, pp. 143-164.

Conti S. (1989) Geologia dell'Appennino marchigiano-romagnolo tra le valli del Savio e del Foglia. Note illustrative alla carta geologica a scala 1:50,000. Boll. Soc. Geol. It., 108, pp. 453-490.

Conti S. (1990). Geologia dell'Appennino marchigiano-romagnolo tra le valli del Savio e del Foglia. Note illustrative alla carta geologica a scala 1:50000. Bollettino della Società Geologica Italiana, 108(3), pp. 453-490.

Conti S. (1995). La geologia dell'alta Val Marecchia (Appennino toscomarchigiano). Note illustrative alla carta geologica a scala 1:50.000. Atti Tic. Sc. Terra, 37, pp. 51-98.

Conti S., Fioroni C., Fontana D. Grillenzoni, C. (2016). Depositional history of the Epiligurian wedge-top basin in the Val Marecchia area (northern Apennines, Italy): a revision of the Burdigalian-Tortonian succession. Italian Journal of Geosciences, 135(2), 324-335. https://doi.org/10.3301/IJG.2015.32

Coratza P. & Giusti C. (2005). Methodological proposal for the assessment of the scientific quality of geomorphosites. Il Quaternario 18(1), pp. 307–313.

Coratza P. & Hobléa F. (2018). The specificities of geomorphological heritage. In: Reynard E., Brilha J. (Eds). Geoheritage. Assessment, Protection, and Management. Elsevier, pp. 87–106. https://doi.org/10.1016/B978-0-12-809531-7.00005-8

Coratza P. & Regolini-Bissig G. (2009). Methods for mapping geomorphosites. in: Reynard, E., Coratza P. & Regolini-Bissig G. (eds.): Geomorphosites, F. Pfeil, München, pp. 89-103.

Cornamusini G., Ielpi A., Bonciani F., Callegari I., Conti P. (2012). Geological map of the Chianti Mts (Northern Apennines, Italy). J. Maps 2012, 8, pp. 22–32. https://doi.org/10.1080/17445647.2012.668423

Cornamusini G., Conti P., Bonciani F., Callegari I., Martelli L. (2017). Geology of the 'Coltre della Val Marecchia' (Romagna-Marche Northern Apennines, Italy). J. Maps 2017, 13, pp. 207-218. https://doi.org/10.1080/17445647.2017.1290555

Cyr A.J & Granger D.E. (2008). Dynamic equilibrium among erosion, river incision, and coastal uplift in the northern and central Apennines, Italy. Geology, 36, 103–106. https://doi.org/10.1130/G24003A.1

D'Ambra S., Giglio G., Lembo-Fazio A. (2004). Interventi di sistemazione e stabilizzazione della Rupe di San Leo. 10° Congress INTERPRAEVENT 2004, Riva del Garda 2:IV/103-114

D'Errico M., Di Staso A., Morabito S., Perrone V. (2014). New stratigraphic data for the Poggio Carnaio Sandstone Fm (Northern Apennines, Italy). Boll. Soc. Geol. It., 133(1), pp. 5-12. https://doi.org/10.3301/IJG.2013.06

Danon M. (2020). Ecopsicologia. Come sviluppare una nuova consapevolezza ecologica, Sansepolcro (AR), Aboca.

De Bruin A. & Jelinčić D.A. (2016). Toward extending creative tourism: participatory experience tourism. Tourism review. https://doi.org/10.1108/TR-05-2015-0018

De Capoa P., D'Errico M., Di Staso A., Perrone V., Perrotta S., Tiberi V. (2015). The succession of the Val Marecchia Nappe (Northern Apennines, Italy) in the light of new field and biostratigraphic data. Swiss Journal of Geosciences, 108(1), pp. 35-54. https://doi.org/10.1007/s00015-015-0177-0

De Feyter AJ. (1991). Gravity tectonics and sedimentation of the Montefeltro, Italy. Geol. Ultraiectina, 35, pp. 1-168.

De Feyter A.J., Molenaar N. (1984). Messinian Fanglomerates: The Colombacci Formation in the Pietrarubbia Basin, Italy. SEPM Journal of Sedimentary Research, Vol. 54. https://doi.org/10.1306/212F84EA-2B24-11D7-8648000102C1865D

Del Monte M. (2003). Caratteristiche morfometriche e morfodinamiche dell'alto bacino del Fiume Orcia (Toscana meridionale). Congr. Geogr. It., Atti XXVIII, pp. 1938–1975.

Del Monte M., Fredi P., Palmieri E.L., Marini R. (2002). Contribution of quantitative geomorphic analysis to the evaluation of geomorphological hazards. In Applied Geomorphology: Theory and Practice; Allison, R.J., Ed.; J. Wiley & Sons: Hoboken, NJ, USA, pp. 335–358.

Della Seta M., Del Monte M., Fredi P., Palmieri E.L. (2007). Direct and indirect evaluation of denudation rates in Central Italy. Catena, 71, pp. 21–30.
https://doi.org/10.1016/j.catena.2006.06.008

Della Seta M., Del Monte M., Fredi P., Palmieri E.L. (2009). Space–time variability of denudation rates at the catchment and hillslope scales on the Tyrrhenian side of Central Italy. Geomorphology, 107(3-4), pp. 161-177.
https://doi.org/10.1016/j.geomorph.2008.12.004

Flores G., Gallardo C. (2021). Creating Shapefile Files in ArcMap from KML File Generated in My Maps. In: Botto-Tobar M., S. Gómez O., Rosero Miranda R., Díaz Cadena A. (eds) Advances in Emerging Trends and Technologies. ICAETT 2020. Advances in Intelligent Systems and Computing, vol 1302. Springer, Cham.
https://doi.org/10.1007/978-3-030-63665-4_15

Di Vittorio A. (2010). Le prospettive del turismo" esperienziale" nel contesto dell'economia italiana. Economia italiana, (2), 523.

Dominici L. (1959). Sant'Agata Feltria illustrata. Provincia di Pesaro e Urbino.

Ekman P. (1992). An argument for basic emotions. Cognition & emotion, 6(3-4), pp. 169-200. https://doi.org/10.1080/02699939208411068

Elmi C., Fanucci F., Nesci O., Beer G., Pignocchi A. (1994). Evoluzione olocenica della linea di riva adriatica dal F. Reno al F. Potenza (Italia centrale). Il Quaternario, 7(1), pp. 305–310.

Elmi C., Colantoni P., Gabbianelli G., & Nesci O. (2002). Holocene shorelines along the central adriatic coast (Italy). GeoActa, 1, pp. 27–36.

Erikstad L. (2013). Geoheritage and geodiversity management - the questions for tomorrow. Proceedings of the Geologists Association, 124, pp. 713–719. https://doi.org/10.1016/j.pgeola.2012.07.003

Ermeti A.L., Sacco D. (2003). Prime ricerche archeologiche nel Castello di Montecopiolo, Studi Montefeltrani, 23, pp. 211-236.

Fagan B.M. (2001). La rivoluzione del clima. Sperling & Kupfer. Milano.

Farabegoli E., Ricci Lucchi F. (1973). Studio sedimentologico di alcuni conglomerati messiniani dell'avanfossa padano-appenninica. Atti Soc. Nat. Mat. Modena, 104, pp. 193-238.

Farsani N.D., Coelho C., Costa C. (2011). Geotourism and Geoparks as novel strategies for socio-economic development in rural areas. Int. J. Tour. Res., 13, pp. 68-81. https://doi.org/10.1002/jtr.800

Ferreira G. (1998). Environmental education through hiking: A qualitative investigation. Environmental Education Research, 4(2), pp. 177-185. https://doi.org/10.1080/1350462980040205

Feuillet T. & Sourp E. (2010). Geomorphological heritage of the Pyrenees National Park (France): Assessment, clustering, and promotion of geomorphosites. Geoheritage 3(3), pp. 151–162. https://doi.org/10.1007/s12371-010-0020-y

Flenghi M. & Flenghi C. (2019). Cella Fausti e il convento di San Francesco in Sant'Agata Feltria. Indagine storica e progetto di ricostruzione dell'antica cella.

Fontemaggi A. & Piolanti O. (1995). Il popolamento nel territorio di Ariminum: testimonianze archeologiche. Pro poplo ariminese, pp. 531-561.

Fuertes-Gutiérrez I., Fernández-Martínez E. (2012) – Mapping geosites for geoheritage management. a methodological proposal for the regional park of Picos de Europa (León, Spain). Environmental management, 50 (5), pp. 789–806. https://doi.org/10.1007/s00267-012-9915-5

Gioia D., Martino C., Schiattarella M. (2011). Long- to short-term denudation rates in the southern Apennines: Geomorphological markers and chronological constraints. Geol. Carpath., 62, pp. 27–41. https://doi.org/10.2478/v10096-011-0003-1

Grandgirard V. (1999). L'évaluation des géotopes. Geol Insubr 4(1), pp. 59–66

Gravelius H. (1914). Grundriß der gesamten Gewasserkunde, Band 1: Flußkunde. Compend. Hydrol. 1914, I, pp. 265–278. https://doi.org/10.1515/9783112452363

Gray M. (2013). Geodiversity. Valuing and conserving abiotic nature. 2nd ed. Wiley-Blackwell, 495 p.

Gulotta G. (2019). Aspetti psicologici del turismo esperienziale. Ricerche di Psicologia. https://doi.org/10.3280/RIP2019-004005

Guerra C., Nesci O. (2013). L'analisi del paesaggio storico come strumento per la comprensione dell'evoluzione geomorfologica e ambientale del territorio. Alcuni casi studio nel Montefeltro. Il Geologo dell'Emilia-Romagna, 48–49, pp. 7–16.

Guerra V., Guerra C., Nesci, O. (2020). Geomorphology of the town of Rimini and surrounding areas (Emilia-Romagna, Italy). Journal of Maps, 17(4), pp. 113-123. https://doi.org/10.1080/17445647.2020.1800527

Guerra V. & Lazzari M. (2020). Geomorphic approaches to estimate short-term erosion rates: An example from Valmarecchia river system (Northern Apennines, Italy). Water, 12(9), pp. 25-35. https://doi.org/10.3390/w12092535

Guerra V. & Lazzari M. (2021). Geomorphological mapping as a tool for geoheritage inventory and geotourism promotion: a case study from the middle valley of the Marecchia River (northern Italy). Actes des 21èmes Journées des Jeunes Géomorphologues, 27(2), pp. 127-145. https://doi.org/10.4000/geomorphologie.15193

Hillman J., Donfrancesco F. & Donfrancesco, P. (2005). Politica della bellezza. Moretti & Vitali.

Horton R.E. (1932). Drainage Basin Characteristics. Trans. Am. Geophys. Union, 13, pp. 350–361. https://doi.org/10.1029/TR013i001p00350

Horton R.E. (1945). Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Geol. Soc. Am. Bull., 56, pp. 275–370. https://doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

Joye Y. & Bolderdijk J.W. (2015). An exploratory study into the effects of extraordinary nature on emotions, mood, and prosociality. Frontiers in psychology, 5, 1577. https://doi.org/10.3389/fpsyg.2014.01577

Knight J., Mitchell W., Rose J. (2011). Geomorphological Field Mapping. In Smith M.J., Paron P., Griffiths J. (Eds.): Geomorphological Mapping. Methods and applications. Elsevier (London), pp. 151-188. https://doi.org/10.1016/B978-0-444-53446-0.00006-9

Kubalíková, L. (2013). Geomorphosite assessment for geotourism purposes. Czech Journal of Tourism, 2(2), 80-104. https://doi.org/10.2478/cjot-2013-0005

Lazzari M. & Schiattarella M. (2008). Confronto tra tassi di erosione fluviale e da franosità in alta Val d'Agri (Appennino meridionale). In Studi di Base Sull'Interazione tra Clima, Tettonica e morfoevoluzione in Italia Meridionale Durante il Quaternario; Boenzi, F., Capolongo, D., Giano, S.I., Schiattarella, M., Eds.; Dibuono Edizioni, Villa d'Agri (PZ): Marsicovetere, Italy, pp. 105–114.

Lazzari M. & Schiattarella M. (2010). Estimating long to short-term erosion rates of fluvial vs mass movement processes: An example from the axial zone of the southern Italian Apennines. It. J. Agron. 2010, 5, pp. 57–66. https://doi.org/10.4081/ija.2010.s3.57

Lombardi F.V. (1999) Mille anni di medioevo, in Allegretti G., Lombardi, F.V. Ambiente storia arte nell'alta Valmarecchia, Il Montefeltro, 2, pp. 89-145.

Lotti L., Garattoni M.C., Biordi M., Parea G.C., Triossi G., Tomasini, Pietramellara C., Giuccioli, Menghi G., Bebi P., Delucca O. (1994). Le grotte di Santarcangelo. Atti della giornata di studi. Santarcangelo, 15 Maggio 1988. Cesena, Società di Studi Romagnoli.

Lubova K.A., Zayats P.P., Ruban D.A., Tiess G. (2013). Megaclasts in geoconservation. sedimentological questions, anthropogenic influence, and geotourism potential. Geologos, 19, 321–335. https://doi.org/10.2478/logos-2013-0017

Melton M.A. (1957). An Analysis of the Relation among Elements of Climate, Surface Properties, and Geomorphology; Department of Geology, Columbia University: New York, NY, USA. https://doi.org/10.21236/AD0148373

Miller V.C. (1953). A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area. In Technical Report 3; Department of Geology, Columbia University: New York, NY, USA.

Mokhtari D., Roostaei S., Khodadadi M., Ahmadi M., Ebrahimi O., Shahabi, H. (2019). Evaluation of the Role of Environmental Education in Manesht and Ghelarang Geotourism Destination, Iran. *Journal of Quality Assurance in Hospitality & Tourism*, *20*(6), pp. 681-708. https://doi.org/10.1080/1528008X.2019.1616039

Moretti L. (2014). Sui sentieri del monte Fumaiolo. Trekking, MTB e cavallo: una guida completa alla scoperta del territorio. Fumaiolo sentieri. Monti Raffaele.

Morucci B. (2003). La demande touristique: une approche de son évolution et de ses perspectives. In J. Spindler & H. Durand (Eds.), Le tourisme au XXI e siècle. Paris: L'Harmattan, pp. 133-155.

Mucivuna V.C., Reynard E., Garcia M.D.G.M. (2019). Geomorphosites assessment methods: Comparative analysis and typology. Geoheritage, 11(4), pp. 1799-1815. https://doi.org/10.1007/s12371-019-00394-x

Nesci O. (2012). Il paesaggio invisibile. In: Verso una nuova interpretazione del paesaggio sardo. Convegno internazionale Urzulei, Architettura e Paesaggio, Comune di Urzulei, pp. 28-32.

Nesci O. & Sacco D. (2010). Geomorfologia, viabilità e popolamento antico: il caso della via Ariminensis. G&T, pp. 111-114.

Nesci O., Savelli D., Diligenti A., Marinangeli D. (2005). Geomorphological sites in the northern Marche (Italy). Examples from autochthon anticline ridges and from Val Marecchia allochthon. Il Quaternario, Italian Journal of Quaternary Sciences, 18(1), pp. 77-89.

Nesci O. & Valentini L. (2016). Landscapes of Central Italy through Science, Poetry and Music. A perspective for educating to the planet sustainability. In EGU General Assembly Conference Abstracts (pp. EPSC2016-3911).

Nesci O. & Valentini L. (2015). Three known marchean geomorphosites presented using geomorphology, poetry and ancient music. A new perspective for the development of the area. In 5th AIGEO National Conference Geomorphology for Society From Risk Knowledge To Landscape Heritage. ITA.

Nesci O. & Valentini L. (2020). Science, poetry, and music for landscapes of the Marche region, Italy: communicating the conservation of natural heritage. Geoscience Communication, 3(2), 393-406. https://doi.org/10.5194/gc-3-393-2020

Origet du Cluzeau C. & Vicériat P. (2000). Le tourisme des années 2010. "La mise en futur de l'offre". Paris: La Documentation française.
https://doi.org/10.1108/eb058370

Otto J.C., Smith M. (2013). Geomorphological mapping. In Clarke L., Nield J. (Eds.) Geomorphological Techniques (Online Edition), Chap. 2, Sec. 6. British Society for Geomorphology, London.

Panizza M. (2001). Geomorphosites: concepts, methods and examples of geomorphological survey. Chinese science bulletin, 46(1), 4-5.
https://doi.org/10.1007/BF03187227

Panizza M. & Piacente S. (2003). Geomorfologia culturale. Prima edizione. Bologna: Pitagora.

Panizza M. & Piacente S. (2014). Geomorfologia culturale. Seconda edizione. Bologna: Pitagora.

Panizza M. & Piacente S. (2009). Cultural geomorphology and geodiversity. Geomorphosites. Pfeil Verlag, Munich, pp. 35-48.

Panksepp J. (1998). Aective Neuroscience: The Foundations of Human and Animal Emotions. Oxford: Oxford university press.

Parea G.C. (1986). I terrazzi marini tardo-pleistocenici del fronte della catena appenninica in relazione alla geologia dell'avanfossa adriatica. Mem. Soc. Geol. It, 35, pp. 913–936.

Pelfini M. & Bollati M.I. (2014). Landforms and geomorphosites ongoing changes: Concepts and implications for geoheritage promotion. Quaestiones geographicae, 33(1), pp. 131-143. https://doi.org/10.2478/quageo-2014-0009

Pereira P., Pereira D., Caetano Alves M.I. (2007). Geomorphosite assess- ment in Montesinho Natural Park (Portugal). Geogr Helv 62(3), pp. 159–168.
https://doi.org/10.5194/gh-62-159-2007

Peretto C. (1994). The origin of Human Population in Italy. The Human Population of Italy: man and Environment in the Past: Census and analysis, Preistoria Alpina, 26, pp. 31-35.

Persi P., Veggiani A., Lombardi F. V., Battistelli M., Renzi G., Allegretti G. (1993). Le frane nella storia della Valmarecchia. Comunità Montana della Valmarecchia, Sant'Agata Feltria, 110.

Petruzzi M., Piscicelli M., Zuppiroli M. (2021). Santarcangelo di Romagna: il sistema di strutture ipogee in rapporto al tessuto urbano storico tra tutela e valorizzazione. pp. 817-828.

Piastra S., Landuzzi A., Cencini C. (2005). Historical landslides (XVII–XIX centuries) from Romagna Apennines, Northern Italy. A cultural approach. 6th Int. In Congress on Geomorphology, Zaragoza, Spain, 410 p.

Pieruccini P. & Coltorti M. (2010). Il monte Carpegna (Marche settentrionali): un atlante dei grandi movimenti franosi. Geologia dell'Ambiente, pp. 239-251.

Pietramellara C., Menghi G. (1994). La rilevazione delle grotte, la forma e la tipologia, in Le grotte di Santarcangelo. Atti della giornata di studi. Santarcangelo,15 Maggio 1988. Cesena, Società di Studi Romagnoli, pp. 39-58.

Piangiamore G. L., Falsaperla S., Eva E., Musacchio G. (2021). Seismic risk communication: let's students show their own way. Annals of Geophysics. https://doi.org/10.4401/ag-8396

Piangiamore G. L., Musacchio G., & Pino N. A. (2015). Natural hazards revealed to children: the other side of prevention. Geological Society, London, Special Publications, 419(1), pp. 171-181. https://doi.org/10.1144/SP419.12

Piangiamore G. L. & Musacchio, G. (2017). Participatory approach to natural hazard education for hydrological risk reduction. In Workshop on World Landslide Forum. Springer, Cham., pp. 555-561. https://doi.org/10.1007/978-3-319-59469-9_50

Pizzuto J. (2011). Riverine environments. The Sage Handbook of Geomorphology. Sage, London, pp. 359-377. https://doi.org/10.4135/9781446201053.n21

Plutchik R. (1980). A general psychoevolutionary theory of emotion. Theories of emotion, 1, pp. 3-31. https://doi.org/10.1016/B978-0-12-558701-3.50007-7

Polidori L. (2015). Turismo esperienziale all'interno della politica di sviluppo rurale dell'Unione europea.

Pralong J.P. (2005). A method for assessing tourist potential and use of geomorphological sites: Géomorphologie. Relief, processus, environnement 3, pp. 189–195. https://doi.org/10.4000/geomorphologie.350

Pralong J.P. (2006). Geotourism: A new form of tourism utilising natural landscapes and based on imagination and emotion. Tourism Review. Mar 1. https://doi.org/10.1108/eb058476

Prebensen N.K., Chen J.S., Uysal M. (Eds.). (2018). Creating experience value in tourism. Cabi. https://doi.org/10.1079/9781786395030.0000

Prentice R.C., Witt S.F., Hamer C. (1998). Tourism as experience: The case of heritage parks. Annals of tourism research, 25(1), 1-24. https://doi.org/10.1016/S0160-7383(98)00084-X

Ravara Montebelli C. (2020). Acqua buona riminese. Sorgenti, acquedotti, fontane e lavatoi: nuove ricerche. Bookstones.

Regolini-Bissig, G. (2010). Mapping geoheritage. E. Reynard (Ed.). Université de Lausanne-Institut de géographie.

Reynard E. & Coratza P. (2013). Scientific research on geomorphosites. A review of the activities of the IAG working group on geomorphosites over the last twelve years. Geogr. Fis. Din. Quat. 36, pp. 159-168.

Reynard E. & Coratza P. (2016). The importance of mountain geomorphosites for environmental education. Examples from the Italian Dolomites and the Swiss Alps. Acta geogr. Slov. 56(2), pp. 291-303. https://doi.org/10.3986/AGS.1684

Reynard E. & Giusti C. (2018). The landscape and the cultural value of geoheritage. In: Reynard, E., Brilha, J. (Eds.), Geoheritage: Assessment, Protection, and Management. Elsevier, Amsterdam, pp. 147-166. https://doi.org/10.1016/B978-0-12-809531-7.00008-3

Reynard E., & Panizza M. (2005). Geomorphosites: definition, assessment and mapping. An introduction. Géomorphologie: relief, processus, environnement, 11(3), pp. 177-180. https://doi.org/10.4000/geomorphologie.337

Reynard E., Fontana G., Kozlik L., Scapozza C. (2007). A method for assessing" scientific" and" additional values" of geomorphosites. Geographica Helvetica, 62(3), pp. 148-158. https://doi.org/10.5194/gh-62-148-2007

Reynard E., Coratza P., Regolini-Bissig, G. (2009). Geomorphosites: definition and characteristics. In Reynard E., Coratza P., Regolini-Bissig, G. (Eds.) Geomorphosites, pp. 63-73. Munich, Germany: Verlag Dr. Friedrich Pfeil.

Reynard E., Perret A., Bussard J., Grangier L., & Martin S. (2016). Integrated approach for the inventory and management of geomorphological heritage at the regional scale. Geoheritage, 8(1), pp. 43-60. https://doi.org/10.1007/s12371-015-0153-0

Reynard E., Pica A., Coratza P. (2017). Urban geomorphological heritage. An overview. Quaestiones geographicae, 36(3).
https://doi.org/10.1515/quageo-2017-0022

Ricci Lucchi F. (1986a). The Oligocene to recent foreland basins of the northern Apennines. In International Association of Sedimentologists Special Publications; Allen, P.A., Homewood, P., Eds.; Blackwell Scientific Publications: Oxford, UK, 1986; Volume 8, pp. 105-139.

Ricci Lucchi F. (1986b). The foreland basin system of the Northern Apennines and related clastic wedges: A preliminary outline. Giornale di Geologia, 48(1–2), pp. 165–185.

Ricci Lucchi F. (1987). Semi-allochthonous sedimentation in the Apenninic thrust belt. Sedimentary Geology, 50(1-3), pp. 119-134.
https://doi.org/10.1016/0037-0738(87)90030-3

Ricci Lucchi, F. (1990). Turbidites on foreland and on-thrust basins of the northern Apennines. Palaeogeogr. Palaeoclimatol. Palaeoecol. 1990, 77, 51–66.
https://doi.org/10.1016/0031-0182(90)90098-R

Ridolfi V., Montaletti V., Santolini R. (2018). Il fiume al centro. L'esperienza del contratto di fiume Marecchia nel quadro del piano strategico di Rimini e del suo territorio. Reticula, ISPRA, pp. 2-8.

Rivas V., Rix K., Frances E., Cendrero A., Brunsden D. (1997). Geomorphological indicators for environmental impact assessment: consumable and non consumable geomorphological resources. Geomorphology 18, pp. 169–182.
https://doi.org/10.1016/S0169-555X(96)00024-4

Rodríguez E. (2001). La valle del Marecchia nel quadro delle comunicazioni tra Toscana e Romagna. pp. 89-107.

Roveri M., Boscolo Gallo A., Rossi M., Gennari R., Iaccarino S.M., Lugli S., Manzi V., Negri A., Rizzini F., Taviani M. (2005). The Adriatic foreland record of Messinian events (central Adriatic sea, Italy). GeoActa, 4(139), 158.

Roveri M., Manzi V., Bassetti M., Merini M. & Ricci Lucchi F. (1998). Stratigraphy of the Messinian post-evaporitic stage in eastern-Romagna (northern Apennines, Italy). Giornale di Geologia, 60, pp. 119–142.

Sacco D. (2004). Il castello di Monte Acuto nel Montefeltro, ricognizione archeologica-considerazioni sulle tipologie difensive. Quaderni dell'Accademia Fanestre, 3, pp. 77–103.

Salovey P. & Mayer J.D. (1990). Emotional intelligence. Imagination, cognition and personality, 9(3), pp. 185-211. https://doi.org/10.2190/DUGG-P24E-52WK-6CDG

Sancisi G. (2020). Turismo sostenibile e paesaggi fluviali: il caso del Marecchia nell'entroterra di Rimini (Bachelor's thesis, Università Ca'Foscari Venezia).

Schiattarella M., Beneduce P., Pascale S. (2004). Comparazione tra i tassi di erosione e sollevamento dell'Appennino Lucano: L'esempio della Fiumara di Tito e Picerno. Boll. A.I.C. 2004, 121–122, pp. 367–385.

Schumm S.A. (1956). Evolution of Drainage Systems & Slopes in Badlands at Perth Anboy, New Jersey. Bull. Geol. Soc. Am., 67, pp. 597–646. https://doi.org/10.1130/0016-7606(1956)67[597:EODSAS]2.0.CO;2

Selli R. (1954). Il bacino del Metauro. Descrizione geologica, risorse minerarie, idrogeologia. Giornal. Geol., 24, pp. 1-214.

Serrano E. & González Trueba J.J. (2005). Assessment of geomorphosites in natural protected areas: the Picos de Europa National Park (Spain). Géomorphologie. Relief, processus, environnement 3, pp. 197–208. https://doi.org/10.4000/geomorphologie.364

Serrano E. & González Trueba, J. J. (2011). Environmental education and landscape leisure. Geotourist map and geomorphosites in the Picos de Europa National Park. GeoJournal of Tourism and Geosites, 8(2), pp. 295-308.

Severi P. & Zaghini M. (1996). Alluvioni terrazzate del conoide del fiume Marecchia. Evoluzione recente della linea di costa e valutazioni in merito alla subsidenza nell'area riminese. In M. Biordi, A. Antoniazzi & M. Barogi (Eds), Alle origini della storia: il Paleolitico di Covignano, Musei Comunali, pp. 79–89.

Sholihah A. B. & Widodo J. (2018). Blended Learning in Heritage Conservation Course: Cultural Mapping and Google My-Maps Platform. DIMENSI: Journal of Architecture and Built Environment, 45(2), 181-188. https://doi.org/10.9744/dimensi.45.2.181-188

Sibi P. & Valletta M. (2014). Paesaggio e morfogenesi… delle emozioni. Atti del Convegno Dialogo intorno al Paesaggio, Culture Territori Linguaggi, 1, 4.

Smith K.G. (1950). Standards for grading textures of erosional topography. American Journal of Science, 248, pp. 655–668. DOI : 10.2475/ajs.248.9.655
https://doi.org/10.2475/ajs.248.9.655

Spreafico M.C., Franci F., Bitelli G., Girelli V.A., Landuzzi A., Lucente C.C., Mandanici E., Tini M.A. Borgatti, L. (2015). Remote sensing techniques in a multidisciplinary approach for the preservation of cultural heritage sites from natural hazard: The case of Valmarecchia Rock Slabs (RN, Italy). In Engineering Geology for Society and Territory-Volume 8. Springer, Cham., pp. 317-321.
https://doi.org/10.1007/978-3-319-09408-3_55

Stamboulis Y. & Skayannis P. (2003). Innovation strategies and technology for experience-based tourism. Tourism management, 24(1), pp. 35-43.
https://doi.org/10.1016/S0261-5177(02)00047-X

Strahler A.N. (1957). Quantitative analysis of watershed geomorphology. Trans. Am. Geoph. Un. 1957, 38, 913–920. https://doi.org/10.1029/TR038i006p00913

Tarquini S., Isola I., Favalli M., Mazzarini F., Bisson M., Pareschi M.T., Boschi E. (2007). TINITALY/01: A new triangular irregular network of Italy. Ann. Geophys., 50, pp. 407–425.

Teslenok K.S., Teslenok S.A., Tereshkin I.P., Dmitriyev P.S. (2021). Possibilities of using Google (My maps) for cartographic visualization of tourist routes InterCarto. InterGIS. GI support of sustainable development of territories: Proceedings of the International Conference. Moscow: MSU, Faculty of Geography, 27(2), pp. 379-393. https://doi.org/10.35595/2414-9179-2021-2-27-379-393

Tinterri R. & Tagliaferri A. (2015). The syntectonic evolution of foredeep turbidites related to basin segmentation: Facies response to the increase in tectonic confinement (Marnoso-arenacea Formation, Miocene, Northern Apennines, Italy). Marine and Petroleum Geology, 67, pp. 81–110. https://doi.org/10.1016/j.marpetgeo.2015.04.006

Tonini L. (1848). Storia civile e sacra riminese (Vol. 1). Tipi Orfanelli e Grandi.

Tonini L. (1856). Rimini dal principio dell’era volgare all’anno 1200. Rimini.

Tormey D. (2019). New approaches to communication and education through geoheritage. International Journal of Geoheritage and Parks, 7(4), pp. 192-198. https://doi.org/10.1016/j.ijgeop.2020.01.001

Tyng C.M., Amin H.U., Saad M.N.M. and Malik A.S. (2017). The Influences of Emotion on Learning and Memory. Front. Psychol. 8:1454. https://doi.org/10.3389/fpsyg.2017.01454

Vai G. & Castellarin A. (1992). Correlazione sinottica delle unità stratigrafiche nell'Appennino settentrionale. Stud. Geol. Camer., Spec. Vol. 1992/2, pp. 171–185.

Valentini L. & Nesci O. (2021). A new approach to enhance the appeal of the Italian territory through art: three study cases from Marche Region. Arabian Journal of Geosciences, 14(3), pp. 1-17. https://doi.org/10.1007/s12517-020-06415-2

Valentini L., Guerra V., Lazzari M. (2022). Outline of experiences of communication methods on geoheritage: a key tool for public awareness and sustainable development of geotourism. In: Pereira P, Monge-Ganuzas M, Bollati IM, Rouget I (Eds.) (2022). ProGEO SW Europe Regional Working Group Virtual Conference on Geoconservation Abstracts Book, 30-31 March, pp. 62-65

Vascanelos C., Moutinho S., Torres J. (2015). Geothics in the context of Sustainability and its Teaching across the Curriculum. In Proceedings of the 8th International Conference of Education, Research and Innovation, Seville, Spain, 16-18 November 2015.

Vegas J., Díez-Herrero A. (2021). An Assessment Method for Urban Geoheritage as a Model for Environmental Awareness and Geotourism (Segovia, Spain). Geoheritage 13, 27. https://doi.org/10.1007/s12371-021-00548-w

Veggiani A. (1955). La fusione dello Zolfo in Romagna nei sec. XV-XVIII, in Studi Romagnoli VI, p. 335-53; 1979 Zolfi e Zolfatari in Romagna, in Cultura Popolare Emilia Romagna, Milano.

Veggiani A. (1983). Degrado ambientale e dissesti idrogeologici indotti dal deterioramento climatico nell'alto Medioevo in Italia. I casi riminesi. Studi Romagnoli, 34, pp. 123-146.

Veggiani A. (1984). Monumenti rupestri nel Montefeltro marecchiese, in Del Bianco P., Culture figurative e materiali tra Emilia e Marche, Studi in memoria di Mario Zuffa, Rimini, pp. 13-31.

Veggiani, A. (1988). La falesia morta e i depositi olocenici anti- stanti lungo la fascia costiera adriatica fra Cesenatico e Cattolica. In M. Bondesan, C. Elmi, O. Nesci, R. Dal Cin & A. Veggiani (Eds), Guida alle escursioni, Gruppo Nazionale di Geografia Fisica e Geomorfologia, Riunione Annuale, pp. 71–82.

Verstappen H.T. (2011). Old and New Trends in Geomorphological and Landform Mapping. In Geomorphological Mapping. methods and applications. Smith M.J., Paron P., Griffiths J. (Eds.). Elsevier. London, pp. 13–38.
https://doi.org/10.1016/B978-0-444-53446-0.00002-1

Wetzel L.R. (2002). Building stones as resources for student research. Journal of Geoscience Education, 50, pp. 404–409. https://doi.org/10.5408/1089-9995-50.4.404

Wilson E.O. (1984). Biophilia. Harvard University Press.

Zafeiropoulos G., Drinia H., Antonarakou A., and Zouros N. (2021). From Geoheritage to Geoeducation, Geoethics and Geotourism: A Critical Evaluation of the Greek Region. Geosciences 11, 9: 381. https://doi.org/10.3390/geosciences11090381

Zaghini M. (1991). Caratteri geomorfologici e idrografici della Valmarecchia. Studi Romagnoli, 42, pp. 25-55.

Zamboni L. & Rondini P. (2021). Les fortifications du premier âge du Fer de Verucchio (Rimini, Émilie-Romagne). In Les espaces fortifiés à l'âge du Fer en Europe. Actes du 43e colloque international de l'Association française pour l'étude de l'âge du Fer (Le Puy-en-Velay, 30 mai-1er juin 2019), 3, pp. 213-220. AFEAF.

Zattin M., Picotti V., Zuffa G.G. (2002). Fission-track reconstruction of the front of the northern Apennine thrust wedge and overlying Ligurian unit. Am. J. Sci., 302, pp. 346-379. https://doi.org/10.2475/ajs.302.4.346

Zingaro M., Refice A., Giachetta E., D'Addabbo A., Lovergine F., De Pasquale V., Pepe G., Brandolini P., Cevasco A., Capolongo D. (2019). Sediment mobility and connectivity in a catchment: A new mapping approach. Science of The Total Environment, 672, pp. 763-775. https://doi.org/10.1016/j.scitotenv.2019.03.461

Zouros N. (2007). Geomorphosite assessment and management in protected areas of Greece. Case study of the Lesvos Island-coastal geomorphosites. Geogr Helv 62(3), pp. 169–180. https://doi.org/10.5194/gh-62-169-2007

Zwoliński Z., Najwer A., Giardino M. (2018). Methods for assessing geodiversity. In Reynard E., Brilha J. (Eds.): Geoheritage. Assessment, Protection, and Management (Elsevier), pp. 27–52. https://doi.org/10.1016/B978-0-12-809531-7.00002-2

SITOGRAPHY

1. Emilia-Romagna Geoportal https://mappe.regione.emilia-romagna.it/
2. Marche open data https://www.regione.marche.it/Regione-Utile/Paesaggio-Territorio-Urbanistica-Genio-Civile/Cartografia-e-informazioni-territoriali/OpenData
3. Toscana Geoportal http://www502.regione.toscana.it/geoscopio/cartoteca.html#
4. Emilia-Romagna geomorphological datasets https://dati.emilia-romagna.it/dataset?tags=geomorfologia
5. Marche geomorphological features https://www.regione.marche.it/Regione-Utile/Paesaggio-Territorio-Urbanistica-Genio-Civile/Cartografia-regionale/Repertorio/Emergenze-geologiche-geomorfologiche-10000
6. Toscana geomorphological features http://www502.regione.toscana.it/geoscopio/geomorfologia.html
7. IGM GAI 1954-1955 flight on Emilia-Romagna Moka app https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/VIGMIGAI1954_H5/index.html
8. Emilia-Romagna thematic map "Geo-environmental itinerary in the Marecchia Valley" https://ambiente.regione.emilia-romagna.it/it/geologia/geologia/geositi-paesaggio-geologico/itinerari/Itinerari-valle-Marecchia/
9. *Paesaggeo* Instagram profile https://www.instagram.com/paesaggeo/
10. Microcosmi page on Natural Park of Sasso Simone and Simoncello website http://www.parcosimone.it/microcosmi2021/
11. Natural Park of Sasso Simone and Simoncello Facebook page https://www.facebook.com/ParcoSassoSimoneESimoncello
12. Memorandum of Understanding for the elaboration of the Strategic Plan and Valmarecchia River Contract http://www.fiumemarecchia.it/wp-content/uploads/Protocollo-CdF.pdf
13. World Water Council website https://www.worldwatercouncil.org/en/hague-2000
14. Sentieri Covignano https://bit.ly/3ms0FLD
15. Covignano, Spadarolo e Vergiano. Sentieri storici e naturalistici. https://bit.ly/3J4ptDj
16. Mappa strutture ricettive e sentieri. https://bit.ly/3srwHes
17. *Paesaggeo* My Maps online map https://bit.ly/3473onL