



The Balzi Rossi Geocultural Site (Liguro-Provençal Coast, NW Italy) – an Iconic Example to Discuss the Connection Between Geosciences and Cultural Heritage

Irene M. Bollati¹ · Roberto S. Azzoni¹ · Annalisa Cevasco² · Olivier Notter³ · Elena Rossoni-Notter³ · Abdelkader Moussous³ · Deirdre D. Ryan² · Elisabetta Starnini⁴ · Andrea Zerboni¹ · Marta Pappalardo² · Manuela Pelfini¹

Received: 2 October 2024 / Accepted: 25 April 2025
© The Author(s) 2025

Abstract

Geocultural sites are locations where the connection between human history and geo-features is meaningful. In areas currently divided also by national boundaries, it is crucial to determine how the landscape influenced the settlement of past human populations. The Balzi Rossi geosite is a long-lasting investigated archaeological area including caves, rock shelters, and open-air archaeological sites located along the Liguro-Provençal Coast, in the Italian territory, not far from the border with France. Therein, a stratigraphic record preserving more than 200 ky of human exploitation of natural resources and response to north-western Mediterranean Sea-level fluctuations and climate change is preserved. Local archaeological evidence encompasses the occupational phases of the Neanderthal population and the appearance of *Homo sapiens*, thus attributing to the Balzi Rossi cliff a very high scientific value. The SPHeritage Project is aimed at deepening interdisciplinary investigations, towards the sustainable promotion of local geocultural heritage in collaboration with community leaders and stakeholders. In this contribution, we discuss the results of a survey performed among an international team of scientists involved in the research project to assess the scientific and cultural value of the site. Additionally, the outcomes of a World Café initiative that involved local community leaders and stakeholders confirm the uniqueness of the Balzi Rossi site and its high potential of promotion. Such activities highlight the possibility of reinforcing the connection between geocultural sites spread along the Liguro-Provençal Coast through the planning of outdoor paths and multimedia activities based on innovative tools. These proposals may improve the territorial governance and strengthen the ‘sense of place’ in local population.

Keywords Geocultural sites · Geoheritage · Mediterranean Sea level change · Prehistory · Paleolithic settlements · Balzi Rossi (Liguro-Provençal Coast)

Introduction

In the last two decades, the concept of geodiversity has been gaining strength, not only for its supportive role towards biodiversity, but also for its intrinsic value (Gray 2004). Additionally, geodiversity is strictly linked with cultural assets. Indeed, Brilha (2018) suggests that *geodiversity sites* represent the best place to appreciate the variety of geological and geomorphological features of planet Earth, and their strict link with biological and cultural features in the specific. Moreover, the term *geoheritage sites* (or *geosites s.s.*, sensu Brilha 2018) refers to those geodiversity sites for which a relevant scientific value has been recognized. Thus, *geoheritage sites* are unique elements for the reconstruction of Earth dynamics in the view of forecasting potential evolutionary

✉ Irene M. Bollati
irene.bollati@unimi.it

¹ Earth Sciences Department “A. Desio”, University of Milan, Via Mangiagalli 34, 20133 Milan, Italy

² Department of Earth Sciences, University of Pisa, Via Santa Maria 53, 56126 Pisa, Italy

³ Museum of Prehistoric Anthropology of Monaco founded by Prince Albert I, 56 bis Boulevard du Jardin exotique, 98000 Monaco, Monaco

⁴ Department of Civilizations and Forms of Knowledge, University of Pisa, via dei Mille 19, 56126 Pisa, Italy

scenarios concerning planet Earth and its resources. These sites of high geoscientific value (i.e., geosites), are becoming also elements of the cultural heritage *sensu latu* (Panizza and Piacente 2003). The term heritage, indeed, means something to be protected and transmitted to future generations, and, if the valuable features to be transmitted are both geoscientific and cultural *sensu stricto* (e.g., archaeological features), the appreciation by the general public is likely to increase further (Bollati et al. 2023). In this sense, the cultural value may be considered one of the geosystem services provided by geodiversity to Society (Gray et al. 2013). In the traditional methodologies used in literature to assess the value of a geoheritage site and to select the most valuable sites (e.g., Brilha 2018), the cultural value is often considered an additional attribute, since the assessment is primarily focused on the geoscientific features. When the cultural value is particularly relevant, specific terms have been applied in the literature for emphasis (see reviews by Pijet-Migoń and Migoń 2022; Bollati et al. 2023): *geoarcheosite* and *archeogeomorphosite* (Fouache and Rasse 2009; Fouache et al. 2012), *archeo-geosites* (Melelli et al. 2016), *cultural geomorphosites* (Niculiță and Mărgărint 2018), and *geoarcheomorphosite* (Brandolini et al. 2019).

A further term introduced by Reynard and Giusti (2018) is *geocultural site* indicating a site where “the geological features interact with cultural elements (historical or archaeological vestiges, cultural or religious monuments, etc.), and the geoheritage value joins the cultural value”.

A real challenge exists in giving value to both the geological and cultural components of heritage (Reynard and Giusti 2018; Bollati et al. 2023) and increase awareness on it, especially since local populations are more prone to protect cultural heritage sites than the natural abiotic heritage sites, thus negatively affecting the implementation of protection policies at the local level. This can be problematic where natural and anthropic-driven changes menace the integrity of natural sites (Prosser et al. 2010; Pelfini and Bollati 2014). The scarce awareness of society about the role of geofeatures and their importance in underpinning the cultural heritage should be emphasized, as also indicated by the European Landscape Convention (<https://www.coe.int/en/web/landscape>) signed in 2000, underlining how a local population living in a territory should be aware of its heritage and of its resources in whole. Geoconservation could hence be boosted through investigating the interconnections between geo- and cultural features (Lahmidi et al. 2022).

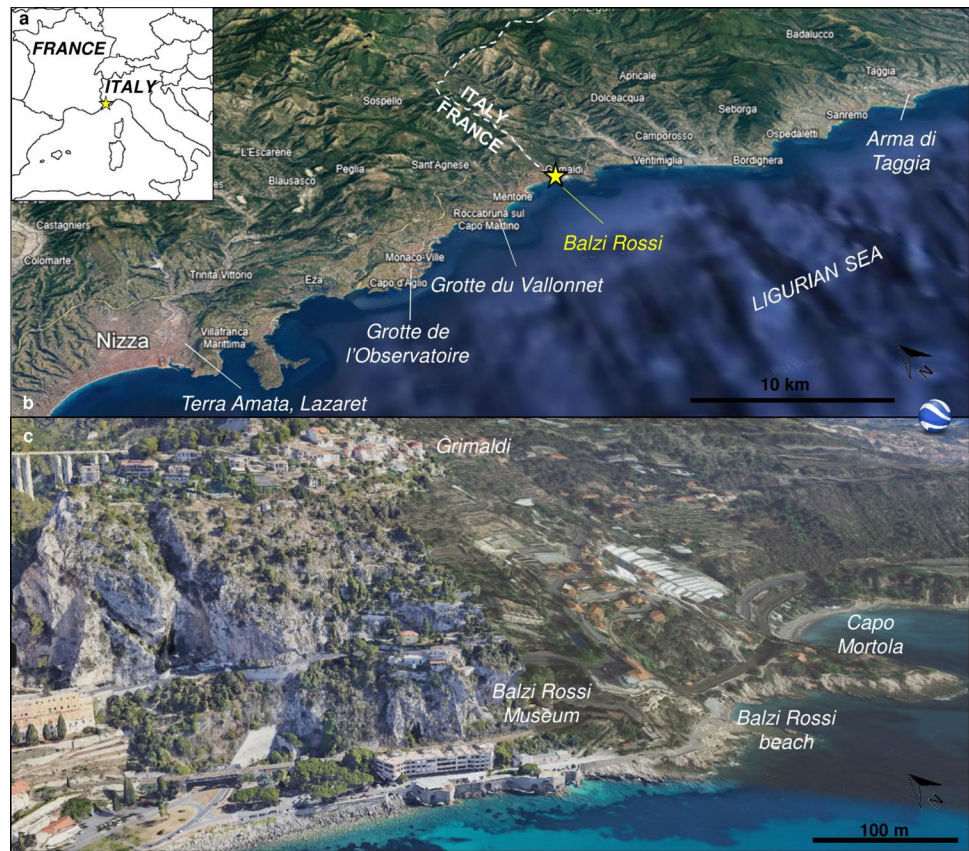
The SPHeritage Project – Lessons for the future from heritage of the past (<https://spheritage.dst.unipi.it/index.php/en/>) (Pappalardo et al. 2023) started in 2021 with the aim of reconsidering the already extensive knowledge existing of the Balzi Rossi archaeological complex, with a focus on the geological, geomorphological, and paleontological features of the sites. The acronym SPHeritage (meaning Sea level,

Population, Heritage) emphasizes the link between sea-level changes and settlement patterns, suggesting it as a major fingerprint on the cultural significance of this site. Balzi Rossi is located along the Liguro-Provençal coast, near to the border between Italy and France (Fig. 1). This project has tried to define how humans adapted in the past to sea-level fluctuations affecting the region. This stretch of Mediterranean coast records evidence of human interaction with ancient marine deposits: e.g. hearths embedded on the top of the coastal landforms, use of marine shell collected along coastal sediments to produce ornaments. The site is mainly known for the archeological heritage unearthed in open air sites and a series of caves and rock shelters sculpted in the Jurassic to Cretaceous limestone. It has been known to local populations and has been the object of school (even with very young pupils) and academic fieldtrips for a very long time (e.g., Candida 1959). The “Museo Preistorico dei Balzi Rossi” is a national museum directly managed by the Italian Ministry of Culture and a repository of part of the prehistoric legacy retrieved during almost two hundred years of investigations (Del Lucchese 1996; Del Lucchese and Starnini 2015a). In the past, the Balzi Rossi Prehistoric Park and Museum have been included in the Interreg 2007–2013 project “Accessit”, aimed at the promotion of the archaeological heritage of the Italo-French border neighboring regions, funded by the European Union with the scope of creating inter-regional cultural heritage networks and bonds between communities across current borders (Del Lucchese and Starnini 2015b). However, what is missing for the general population is the strict connection between the archeological heritage and the natural environment underpinning it: mainly rocks and landforms sculpted in thousands or million years of geological history. For that reason, one of the aims of the SPHeritage Project is to interact with local community leaders and stakeholders to disseminate knowledge and awareness and to reinforce the connection between them and the geocultural heritage extending along the coastline of western Liguria, thus improving the territorial governance and cultural services in the area. In this paper we present the Balzi Rossi geocultural sites, analyzing the geosite databases and the results of the survey completed by the international team of research scientists working within the SPHeritage Project to delineate the scientific value of the site. Finally, the results of a discussion with local community leaders and stakeholders, among which touristic associations, will be presented and discussed to draw conclusions on the best practices to promote the Balzi Rossi site.

The Balzi Rossi Geosite

The SPHeritage Project has the following main aims: i) to obtain new scientific proofs on the magnitude and chronology of sea-level fluctuations over the last 400 ky along the

Fig. 1 Location of the Balzi Rossi site along the Liguro-Provençal Coast at the border between Italy and France (a). 3D views from Google Earth 3D ©. The sites mentioned within the manuscript are depicted on the larger scale map view (b), while detail is provided on the Italian coastal stretch where Balzi Rossi is located (c)



Liguro-Provençal Coast; ii) to investigate the vulnerability of ecosystem biodiversity to global warming during past interglacial stages; iii) to detect the response of the different human communities during the Paleolithic, namely *Homo neanderthalensis* versus *Homo sapiens*, to environmental changes due to sea-level changes; iv) to disseminate the results of this research to increase awareness in local community leaders and stakeholders about the real value of the Balzi Rossi site. As with many projects, the paleoenvironmental reconstructions are integral to the study of human evolution; in this case the perspective is mirrored, and human cultures become proxies for detecting environmental changes. These data may also help in the timely design of the most appropriate strategies for mitigating the risk to, not only visitors to the site, but also the geoheritage site itself. Both of them are becoming even more vulnerable considering the present context of increasing extreme meteorological events, predicted future sea-level rise due to global climatic change and local seismicity (Pappalardo et al. 2023).

The Balzi Rossi area takes its name from the reddish colour of the clay-rich rock coating a large part of the cliff. It is famous (Barale 2016) for the archaeological heritage including the evidence of early human presence since at least 250 ka BCE (Yokoama 1989) till the end of the upper Palaeolithic (ca. 12 ka BCE). The geocultural complex include 7 caves (Costantini, Fanciulli, Florestano, Caviglione, Barma

Grande, Bausu da Ture, Prince of Monaco); 4 rock shelters (Lorenzi, Mochi, Blanc-Cardini, Bombrini), 2 open air sites of archaeological and geological interest (Ex-Birreria, Ex-Casinò) and 5 sites of naturalistic/geological interest (Grotte Voronoff, Gerbai, Grimaldi, della Scimmia, della Torre) (Fig. 4). The integrity of 2 sites, the Barma Grande and the Bausu da Ture is unfortunately compromised: both were partially/totally destroyed by quarrying at the beginning of the twentieth century and the first was also blown-up during World War II, although part of their relevant heritage is still preserved in museums and repositories (Ryan et al. 2024).

Geological and Geomorphological Features

The Balzi Rossi archaeological area developed on a Jurassic to Cretaceous limestone/dolomite bedrock, fractured and faulted by Cenozoic tectonics (Fig. 2). Cretaceous marls outcropping at the bottom of the Prince of Monaco Cave (Vileneuve et al. 1906–1912) witness an overthrust structure that displaced the Cretaceous formations, as described for the first time by Simone (1968–1969). Moderate regional uplift affects the mountain range and the continental shelf (Dallagiovanna et al. 2017).

Local geomorphological features have been shaped by the interplay of tectonics, rock hardness and susceptibility to erosion, and climate fluctuations and sea-level change,

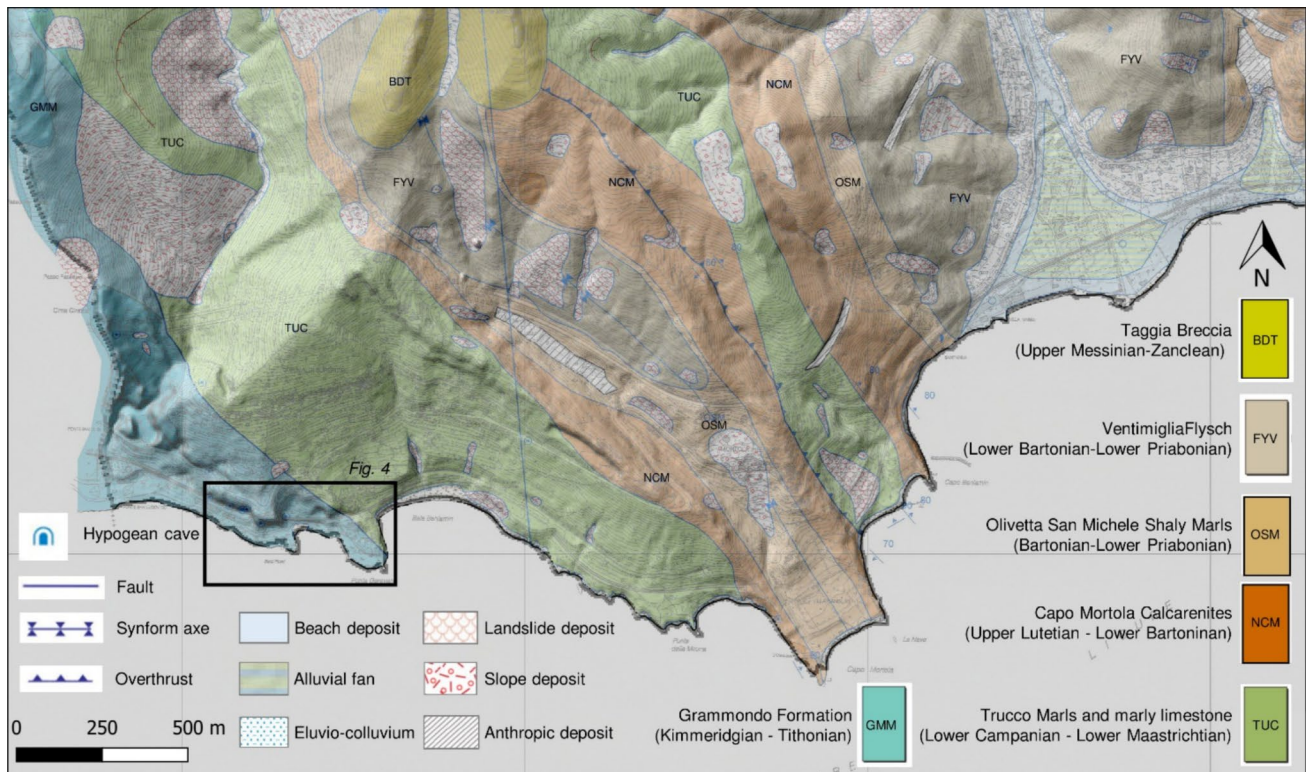


Fig. 2 Geological map from the Ventimiglia and Dolceacqua CARG sheets 1:50.000 (source: Geoportale of the Liguria Region, <https://geoportal.regione.liguria.it/>). The black box indicates the location of the map in Fig. 4

throughout the Cenozoic and especially in the Quaternary (Figs. 3 and 4). The study site is located at the base of a steep slope, the toe of which is shaped in the form of a plunging cliff, coincident with a major fault plane. The upper edge of the cliff reaches the height of ca. 100 m a.s.l. with the base of the cliff at 5 m below sea level. A second submerged cliff, the top of which being around 30 m b.s.l., stretches parallel to the former. Karst features are widespread in the area and include the atrial part of caves, pockets filled of cave clastic sediments and speleothems, and small-scale epikarst features like potholes.

The Balzi Rossi caves and rock shelters correspond to ancient underground cavities exposed to the surface by the cliff retreat. Speleothems are occasionally preserved inside them. Microforms left by limestone dissolution affect the bedrock where exposed. Remnants of reworked *terra rossa* paleosoils (the insoluble product of limestone dissolution) fill the bedrock fissures and fractures and can be found mixed with the products of slope degradation, forming the matrix of the angular breccia at the foot of the cliff. The deposit consists of gravity driven-scrree but archaeological excavations highlighted the stratified architecture of slope deposits, witnessing alternation of climatic phases, including those in which periglacial or aeolian processes were dominant. The cave walls bear traces of modelling action exerted by the

sea during multiple interglacials: marine notches, lithophaga hole bands and, on the bottom, potholes and associated sills. These traces have been displaced by moderate tectonic uplift ongoing throughout the Quaternary. Marine deposits inside the caves have been extensively removed by archaeological excavations.

Anthropogenic activities have massively impacted and continue to influence the landscape. The most ancient human intervention was the coastal road “Aurelia” built by the Romans about 2 ka ago, traces of which are still preserved along the coast. Later, mostly since the 19th century, quarrying, the installation of lime kilns, the construction of the railway line and tunnels, and the construction of residential and other buildings have altered the natural landscape. The most devastating impact, though, occurred during World War II when coastal defences were built and, the Barma Grande cave was blown up to block the railway tunnel running behind the cave. Archaeological excavations themselves, ongoing since the early 19th century, have also been a mean of natural landscape modification.

Archaeological Features

The earliest archaeological excavations at the Balzi Rossi prehistoric complex dates to the middle nineteenth century



Fig. 3 Examples of relevant geomorphological evidence in the Balzi Rossi archaeological complex: **a** General view of the Balzi Rossi cliff, coincident with a fault plane and sealed by a scree slope at the base. The triangular shape of the Caviglione Cave opening is visible on the right. **b** The interior of the Prince of Monaco Cave preserves marine and terrestrial landforms and deposits testifying alternation

of climatic phases during the Pleistocene. **c** The Ex Casinò section exposing the stratified architecture of slope deposits topping the bed-rock affected by fossil lithophaga holes. **d** The bottom of the Barma Grande Cave, shaped in the form of a big pothole in which traces of the pristine marine deposit, extensively removed by archaeological excavations, are visible

and most of the digging activities took place during the late 19th and early twentieth century. However, research at some sites continued into the recent past or is still ongoing (Ryan et al. 2024 and literature therein).

The archaeological complex includes twelve Palaeolithic sites at varying elevations, among which are two open-air sites, namely Ex-Casinò and Ex-Birreria that are on top of a rocky platform (Figs. 3c and 4). Three archaeological sequences are preserved inside rock shelters (namely Lorenzi Rock shelter, Mochi Rock shelter, and Bombrini Rock shelter) and the remaining are in the atrial part of caves (namely Costantini Cave, Fanciulli Cave, Florestano Cave, Caviglione Cave, Barma Grande, Bausu da Ture, Mochi Cave and Prince of Monaco Cave). These sites are all located near the foot or at middle elevations within the cliff. The Voronoff Cave and Grimaldi Cave are found at higher elevations, at ca. 100 m a.s.l. (Fig. 4).

Human occupation dating to the middle and/or upper Palaeolithic has been detected at every site except for the

caves located at higher elevations (Voronoff and Grimaldi; Fig. 4). The Palaeolithic cultures so far identified at the sites include the Mousterian, Gravettian, Epigravettian, Aurignacian and Protoaurignacian phases, making Balzi Rossi a worldwide renewed focal point to study and understand the Middle/Upper Palaeolithic transition, the demise of the last Neanderthals and the arrival of the first *H. sapiens* (Benazzi et al. 2015). Despite the destruction of many parts of the archaeological deposit due to the construction of the railway that crosses the prehistoric park, a large part of it is still preserved and archaeologically unexplored, especially the layers corresponding to the Neanderthal presence and activity.

The very rich prehistoric heritage unearthed during almost 200 years of excavations, composed of human remains from burials, portable art, lithic and animal bone assemblages, constitutes the remarkable collections of several Museums, among which are, besides the Prehistoric Museum of the “Balzi Rossi”, the National Archaeological Museum of Saint-Germain-en-Laye (France), the Musée

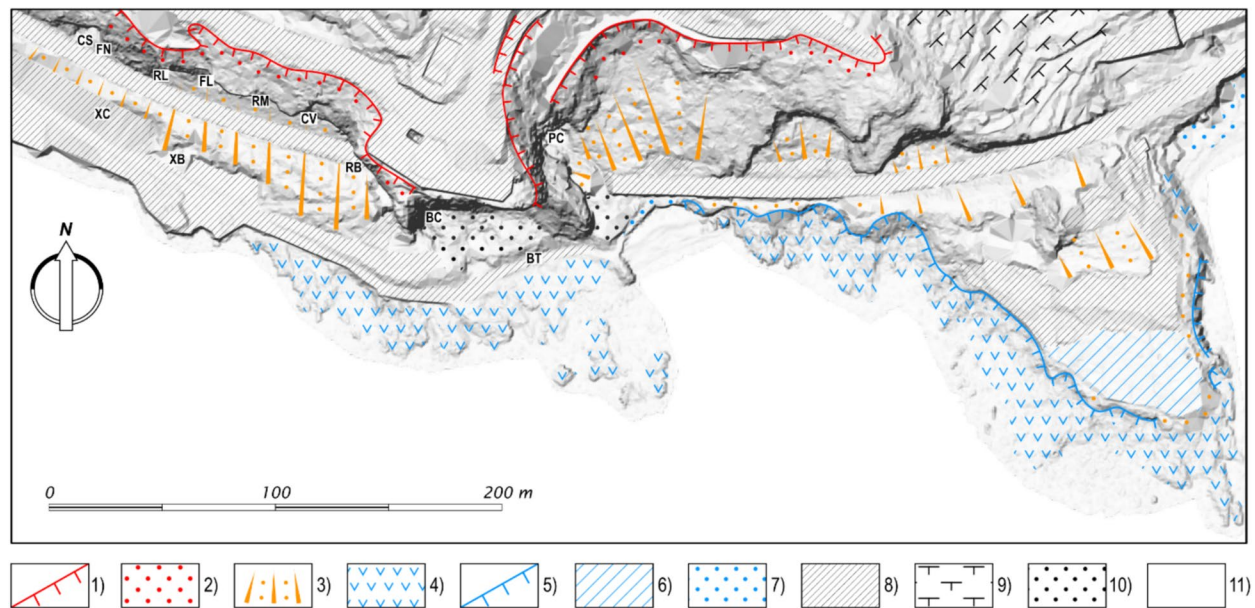


Fig. 4 Geomorphological sketch map of the Balzi Rossi prehistoric complex. Legend: 1) cliff; 2) talus fed by rockfalls; 3) relict scree slope; 4) ramp; 5) coastal cliff; 6) marine terrace; 7) beach (pebbly); 8) anthropogenically reshaped area; 9) agricultural terracing; 10) quarry debris; 11) bedrock. The labels indicate i) open-air sites: Ex-Casinò (XC) and Ex-Birreria (XB); rock shelters: Riparo Lorenzi

(RL), Riparo Mochi (RM), Riparo Bombrini (RB); ii) caves: Grotta Costantini (CS), Grotta dei Fanciulli (FN), Grotta di Florestano (FL), Grotta del Caviglione (CV), Barma Grande (BG), Bausu da Ture (BT), Grotta del Principe di Monaco (PC). The individual site names are given in Italian; “riparo” means rock shelter and “grotta” means cave

d'Anthropologie préhistorique of the Principate of Monaco, the Musée de Préhistoire Régionale de Menton (France).

The Geosite

The Liguria Region is rich in geological heritage and features high geodiversity (Ferrando et al. 2021, 2023). It is where one of the first UNESCO Global Geoparks was established (Beigua Geopark, Marescotti et al. 2022). The Italian territory is covered by different geosites inventories, in many cases overlapping each-other. Five geosites are listed within the municipality of Ventimiglia in the National Inventory of Geosites of ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale; <https://sgi.isprambiente.it/GeositiWeb/Default.aspx>), in the Liguria Region Geosite inventory (<https://geoportal.regione.liguria.it/>), and in the Imperia Province geosites lists (https://www.provincia.imperia.it/sites/default/files/allegati/ptc-elaborati-pdf/Allegato_1_Geotopi.pdf) (Fig. 5; Table 1). Those inventories include almost the same geosites but with some variations, especially concerning the primary interest of the Balzi Rossi site (Table 1).

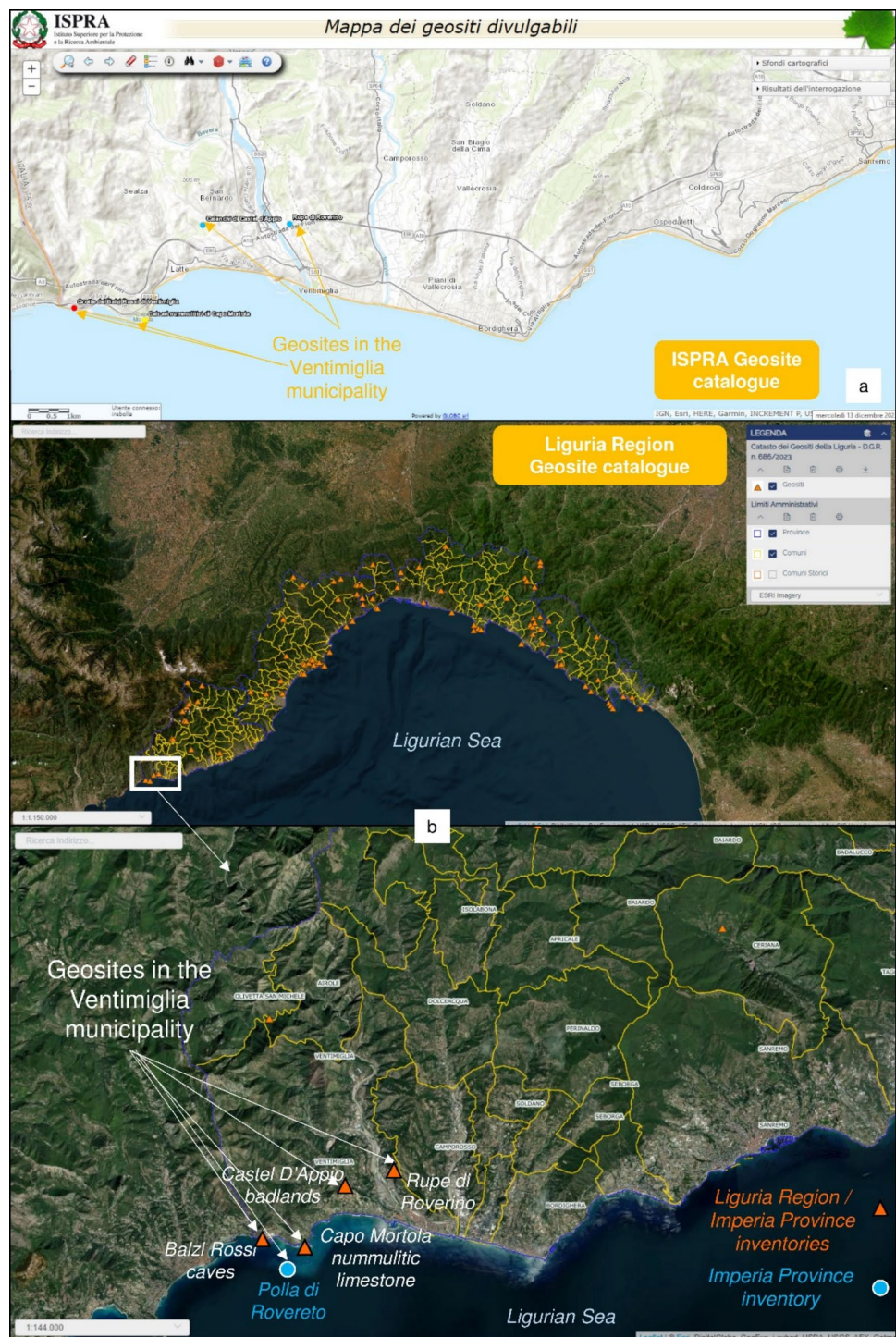
The Balzi Rossi area is listed within all the 3 inventories with a national level of importance. In the ISPRA catalogue the site has been inserted according to the paleontological (primary, scientific) and archaeological (primary, contextual) interests. It is defined as rare, exemplary, and

representative. Moreover, it is defined in a discrete level of conservation, with a low to medium (non-critical) degree of potential degradation for natural or anthropic causes. It is protected under the landscape protection law, and new interventions and impacts for urbanization are prohibited. It is worth noting the high level of urbanization typical of the Liguria Coast, including the international railway encroaching on the caves.

In the surrounding Ventimiglia municipality, there are other geosites inventoried in the 3 different lists (Fig. 5; Table 1): Capo Mortola nummulitic limestone, Rupe di Roverino i.e., (Roverino Cliff), Castel d'Appio badlands, Mt. Grammondo debris cones and the Polla di Rovereto (i.e., Rovereto undersea freshwater spring). This last one is only reported in the Imperia province geosite list.

All the geosites of the Liguria Region have been included in a recent map (Ferrando et al. 2023) and the subject of research aimed at quantitatively assess their value (Ferrando et al. 2021) according to their scientific and additional (e.g., cultural, scenic) values, their potential for use and degradation risk. Unexpectedly, despite the national relevance of the Balzi Rossi site, the values obtained by Ferrando et al. (2021) are lower than those of the other sites in the Ventimiglia municipality. In more detail, Ferrando et al. (2021) suggest, for the Balzi Rossi area, high levels of integrity, interpretative potential, and accessibility, but a medium to low representativeness, rareness, scenic value, cultural,

Fig. 5 The geosites extracted from the WebGis of the ISPRA catalogue (Istituto Superiore per la Protezione e la Ricerca Ambientale; <https://sgi.isprambiente.it/GeositiWeb/Default.aspx>) (a), and of the Liguria Region Geosite inventory (<https://geoportal.regione.liguria.it/>) (b), in this second case indicating also the Imperia Province geosites



and secondary interest, these two latter potentially linked. Moreover, according to the authors, the site is undergoing a relatively high degradation risk. The potential threats to the sites come both from natural processes (e.g., gravity-related processes), as well as from human impact, as the area has been subject to intensive urbanization.

Outside the Ventimiglia municipality, along the Liguria Coast towards the east, in the locality of Arma di

Taggia (Fig. 1a), there is another coastal cave where the archaeological heritage is very significant and where scientific investigations were conducted on archaeological and paleontological heritage and sea-level fluctuations (Isetti et al. 1962; Federici and Pappalardo 2006; Costanzo et al. 2024): the *Grotta dell'Arma*. This site was inventoried only in an older version of the Liguria region

Table 1 List of geosites in the Ventimiglia municipality available in the ISPRA catalogue (Istituto Superiore per la Protezione e la Ricerca Ambientale (<https://sgi.isprambiente.it/GeositiWeb/Default.aspx>), in the Liguria Region Geosite inventory (<https://geoportal.regione.liguria.it/>), in the Imperia Province geosite list, and reported in Ferrando et al. (2021)

Source	ID	Primary interest	Secondary or contextual interest	Interest degree	Degradation risk
Balzi Rossi Caves					
ISPRA Catalogue	994	Palaeontology	Geomorphology, Archaeology	National	Not critical
Liguria Region Catalogue	96	Palaeontology	Archaeology	National	Not critical
Imperia Province Catalogue	g16	Geomorphology	Education	/	/
Ferrando et al. (2021)	63	Geomorphology	/	/	/
Capo Mortola nummulitic limestones					
ISPRA Catalogue	942	Palaeontology	Education	Regional	Not critical
Liguria Region Catalogue	36	Palaeontology	Education	Regional	Not critical
Imperia Province Catalogue	g19	Palaeontology	Education	/	/
Ferrando et al. (2021)	57	Geology	/	/	/
Rupe di Roverino					
ISPRA Catalogue	949	Geomorphology	Landscape view	Local	Not critical
Liguria Region Catalogue	29	Geomorphology	Landscape view	Local	Not critical
Imperia Province Catalogue	g18	Stratigraphy	Geomorphology	/	/
Ferrando et al. (2021)	62	Geology	/	/	/
Castel D'Appio badlands					
ISPRA Catalogue	948	Geomorphology	Landscape view	Local	Not critical
Liguria Region Catalogue	29	Geomorphology	Landscape view	Local	Not critical
Imperia Province Catalogue	g17	Geomorphology	Landscape view	/	/
Ferrando et al. (2021)	61	Geomorphology	/	/	/
Mt. Grammondo debris cones/-Manti detritici del Grammondo – Longoira					
ISPRA Catalogue	935	/	/	/	/
Liguria Region Catalogue	/	/	/	/	/
Imperia Province Catalogue	g9	Geomorphology	Landscape view	/	/
Ferrando et al. (2021)	51	Geomorphology	/	/	/
Polla di Rovereto					
ISPRA Catalogue	/	/	/	/	/
Liguria Region Catalogue	/	/	/	/	/
Imperia Province Catalogue	g2	Geomorphology	/	/	/
Ferrando et al. (2021)	/	/	/	/	/

geosite catalogue (Brancucci and Paliaga 2008) but has been removed from the current list.

To the west, along the French coast not far from the Italian border, three more sites (*Vallonnet*, *Terra Amata* and *Lazaret*) display traces of raised marine deposits and prehistoric human settlement up to 1.2 Ma old (De Lumley et al. 2001). Despite the importance from an archaeological and geomorphological point of view, these sites are not listed in the French inventory of Geosites (<https://inpn.mnhn.fr/accueil/recherche-de-donnees/inpg>). Anyway, they are considered as historical monuments and, as such, placed under the authority of the Ministry of Culture (<https://www.culture.gouv.fr/espace-documentation/Bases-de-donnees/Fiches-bases-de-donnees/Merimee-une-base-de-donnees-du-patrimoine-monumental-francais-de-la-Prehistoire-a-nos-jours>).

Methods

The method applied here for promotion and geoconservation of the geocultural site of Balzi Rossi consisted of two steps. The first one focused on the qualitative assessment of the value of the site based on interviews with experts involved in scientific research at the site. This step involved specifically researchers participants to the SPHeritage Project. During the second step, the obtained results were disseminated in a direct discussion with local community leaders and stakeholders. This step was essential for identifying the best ways to promote the site, considering both its features and the needs of local community leaders and stakeholders. The two steps are described in detail in the next sections. Figure 6 depicts the complete workflow.

Step 1: The Qualitative Evaluation of the Balzi Rossi Site Through a Participatory Approach

The qualitative evaluation of the Balzi Rossi geocultural site was based on a simplified version of the methodology adopted by Bollati and Zerboni (2021) (Fig. 6). A survey was distributed within the international team of scientific experts participating to the SPHeritage Project using Google Forms © to assess the real scientific meaning of the site, the opportunities and the limits of geoconservation and promotion practices. After providing the experts with the definition of geocultural site according to Reynard and Giusti (2018), a series of questions were proposed, subdivided in 4 main sections, the first 3 composed of multiple choice, while the fourth consisted of open questions:

1. *Research topics and type of involvement in the project* – In this section the scientists selected what topics they are working on at the Balzi Rossi site, and how long they had been working at the site, because many of them had been only recently recruited for the project.
2. *Qualitative assessment of the global value of the site* – The parameters usually applied to geoheritage site assessment were presented in a simplified version (from Bollati and Zerboni 2021; Fig. 6) proposing a quantitative methodology of assessment of geosites. This choice was made since the greatest part of participants have never applied the methodology and may not have understood how to interpret the many categories. Moreover, the criteria were applied to a single site and a numeric score is not the goal of the project. The following features were analyzed: scientific representativeness, educational exemplarity, diversity of geofeatures, relevance for the scientific community, integrity, rareness (scientific value; Fig. 6); relation between cultural and geofeatures, relation between biotic (non-human) and abiotic features, relevance for socio-economic and touristic proposals (additional values; Fig. 6).
3. *Assessment of conservation status and promotion proposals* – In this section, opinions are solicited regarding various types of geoconservation issues. Following the practice of García-Ortiz et al. (2014) and Pelfini and Bollati (2014) conservation issues included: sensitivity of the site (i.e., susceptibility or predisposition of a site to damage or destruction,); fragility of the site (i.e., probability for a site to being damaged or destroyed by intrinsic factors, like natural processes); vulnerability of the site (i.e., probability for a site to being damaged or destroyed by extrinsic factors, like human impact). Then, researchers were requested to propose promotion opportunities as a geocultural site evaluating the visibility of the site, the suitability of the topic for different kinds of public, the suitability of conditions of accessibility to the

site (potential for use; Fig. 6). Finally, they were asked to indicate the most appropriate types of promotional activities (promotion opportunities; Fig. 6).

4. *Open questions* – This section was made for collecting further considerations and further proposals regarding the site (promotion opportunities; Fig. 6).

Step 2: The Involvement of Local Community Leaders and Stakeholders in Defining Geoconservation and Promotion Priorities

To understand what perception the local community leaders and stakeholders had about the Balzi Rossi geocultural site, a workshop was organized at the Museo Civico in Sanremo, in one of the main towns, ca. 25 km far from the study area. The morning was devoted to oral presentations about the recent results of scientific research at the site and on analogous case studies from the Mediterranean basin, while the afternoon was dedicated mainly to present the scientists' perspectives of Balzi Rossi's value, as per the results of the survey data. The interlocutors were mainly local community leaders and stakeholders of the Liguria region and Imperia Province (e.g., managers of local entities, museums directors and collection curators, cultural heritage officers of the local Superintendence, tourism associations). The aim of this second part was to discuss and to raise awareness about geocultural heritage by showing and interpreting the results obtained through the survey of the experts.

The results of the meeting will serve as a base for potential future coordinated actions to promote and preserve the Balzi Rossi geocultural site. The meeting was organized following the format of the "World Café" (<http://www.theworldcafe.com>), which promotes the dialogue among large groups. Such discussions are based on 7 actions: setting a context, creating a hospitable space, exploring questions that matter, encouraging everyone's contribution, connecting diverse perspectives, listening together for patterns and insights, sharing collective discoveries. In this specific case, the meeting progressed as follows: i) scientific experts explained which is the value of the geocultural sites through the results of the survey (Step 1); ii) three working groups (tables) were set, trying to mix the types of participants; iii) opening of the discussion on what could be the opportunities to promote the site; which could be the targets; which could be the tools; iv) a representative for each "table" showed and summarized the results through the use of keywords. The moderator, finally, put together all the suggestions, launching the opportunity to apply for specific calls on the promotion of the territory. The initiative was also disseminated in the local newspaper to increase visibility and spread awareness about the ongoing project of territory promotion (<https://www.sanremonews.it/2023/03/02/mobile/leggi-notizia/argomenti/eventi-1/articolo/sanremo-2023-spher>

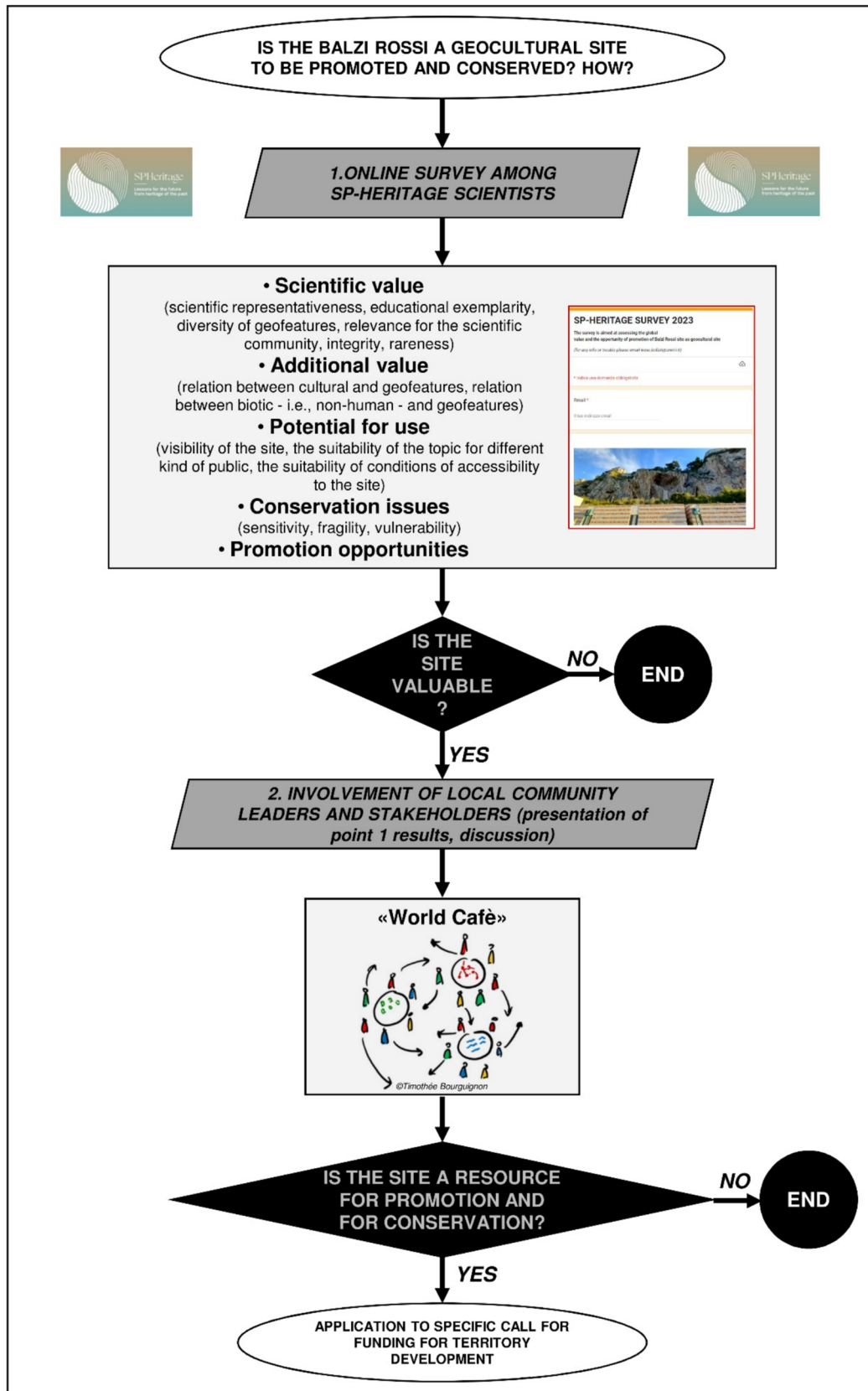


Fig. 6 The workflow adopted during the evaluation of Balzi Rossi potentialities

[itaggio-un-progetto-internazionale-sui-cambiamenti-climatici-al-museo-civico.html](https://www.sciencedirect.com/journal/geoheritage-un-progetto-internazionale-sui-cambiamenti-climatici-al-museo-civico.html)).

Results

Step 1: The Qualitative Evaluation of the Balzi Rossi Site Through a Participatory Approach

In Figs. 7, 8, 9, and 10 the results of the qualitative evaluation are graphed not distinguishing among the participants to the survey.

The total number of experts answering to the survey is 23. Most of them (70%) have been involved specifically on the SPHeritage Project (beginning in 2021), while the others (30%) have been working at the site for a longer period (Fig. 7a). The greatest part of them are geomorphologists (31%), followed by archaeologists (26%), geoheritage specialists (9%), geopedologists (9%), seismostratigraphists and paleomorphologists (9%), geoarchaeologists (4%), palaeontologists (4%), tephrochronologists (4%), and management specialists (4%) (Fig. 7b).

Concerning the scientific value (Fig. 8), the degree of representativeness of the site according to the proper topic is exemplary for 39% of specialists, good for 44% of experts and discrete for the 17% of them (Fig. 8a). For the greatest part of experts (39%) the site has an excellent educational value, even if for the 22% of them the topic could be difficult for non-experts, and the educational exemplarity is poor for

the remnant 17% (Fig. 8b). For the 87% of experts the site is featured by several and different elements, and only 1% individuate only 1 type of interest; the 9% does not answer to this question (Fig. 8c). For the 65% of scientists the site is of reference in the framework of global literature of the topic, favouring topic progression, for the 22% and 13% it provides new information on the global context (Fig. 8d) and on the regional one respectively. The site is integer for the 39% of the surveyed people, while 57% indicates a bad conservation of elements of interest. The 4% does not answer to this question (Fig. 8e). The level of rareness is global for the 52% of experts, is national for the 44%, and 4% did not answer to the question (Fig. 8f).

Specific and/or unique relations exist between the cultural value (e.g., archaeological features) and geofeatures for the 96% of respondents (Fig. 9a), while 4% did not answer. The opinions on the relations between biotic (non-human) and abiotic features are more scattered: abiotic features *condition* the presence of biotic ones for the 57% of experts, while *determine* the presence of biotic ones for the 9% of them. In the first case the relation is less strong than in the second case. Indeed, in the second case, if the abiotic features do not exist, also the biotic elements will not. For the 13% of them it is to be noted the presence of fauna and flora of interest. The remaining respondents did not indicate any specific option (17%) while the 4% indicates that no relation exists at all (Fig. 9b). 78% of respondents affirm that the site is currently used, but under permissions, even if 13% underline that the touristic offer is not yet well structured (Fig. 9c). For

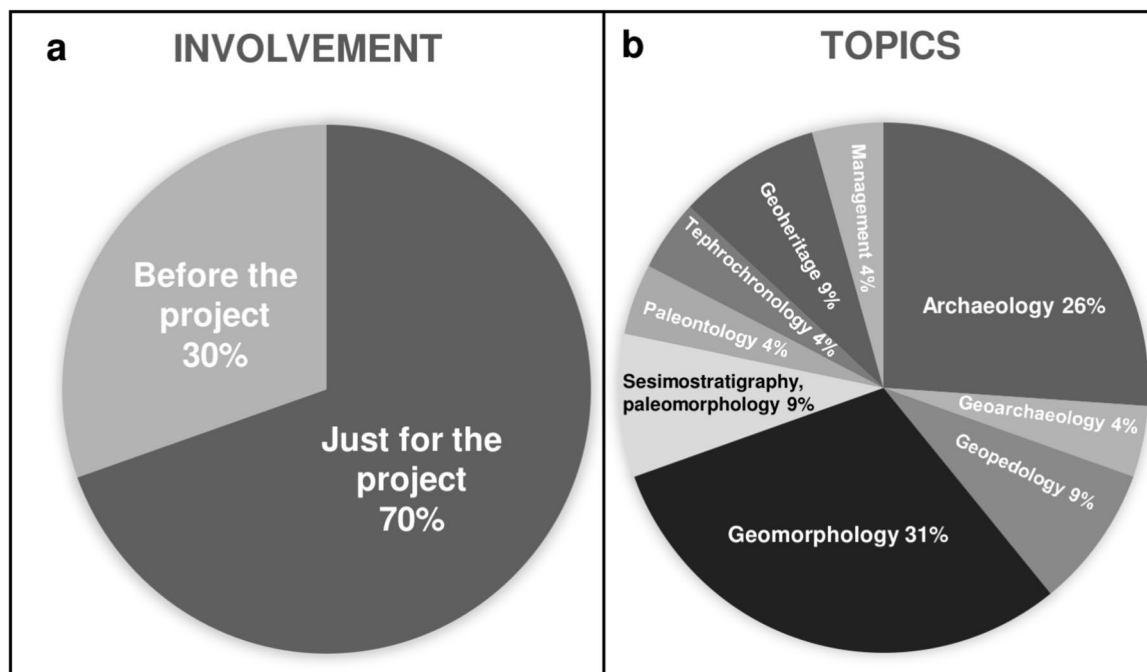
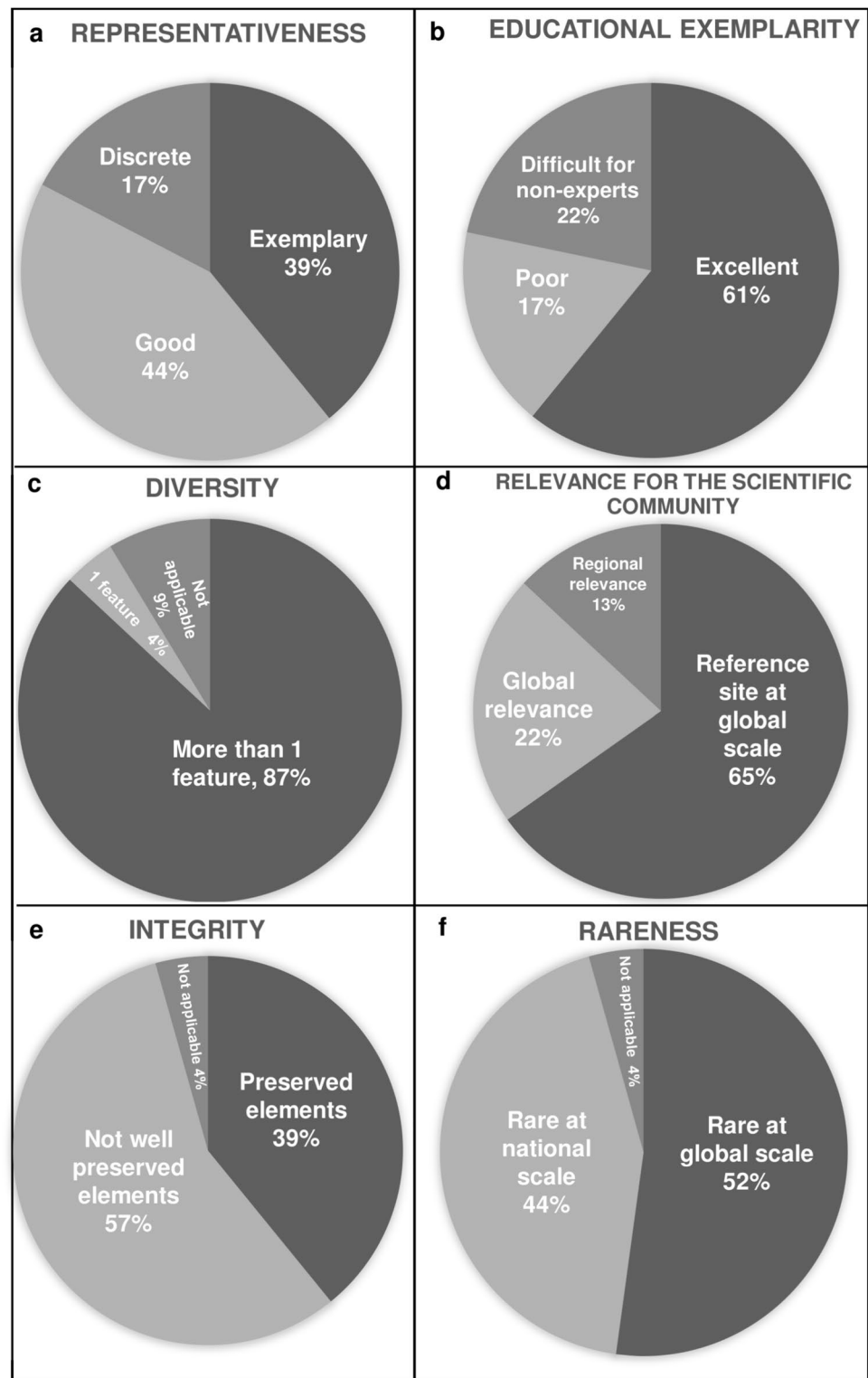


Fig. 7 Experts working at Balzi Rossi defined by (a) how long they have been working at the site, and (b) their expertise

Fig. 8 Descriptive parameters for the different values as assessed by the experts



the 57% of experts implemented measures are needed for an adequate promotion to the sites (Fig. 9d).

The site is considered sensitive to modifications by the 44%, and 39% of respondents should be also added to this category since they consider the possibility the site will

become even more sensitive if opened without any kind of regulation to the public. A variable percentage of experts indicate that the site is fragile respect to intrinsic factors (57%) and vulnerable respect to external factors (39%), even more if the site is opened to the public without any

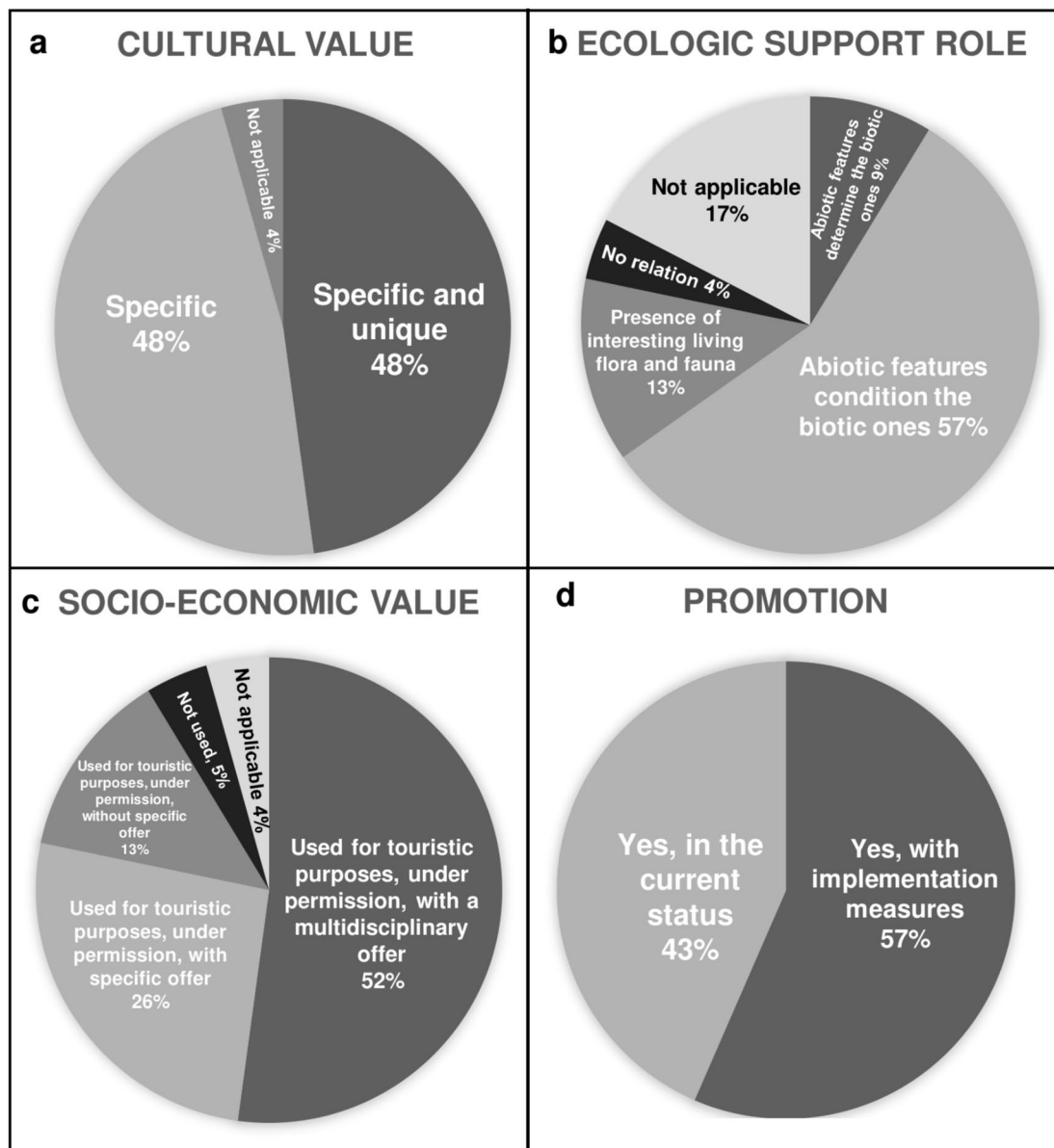


Fig. 9 Additional values and promotion strategies. The cultural value (a), the ecological support role (b), the socio-economic value(c) and the promotion opportunities (d)

regulation (with the percentage increasing to 26% and 39% respectively) (Fig. 10). As mentioned above, respondents underline how implementation measures are needed in the view of opening to the public, but at the same time there is the need of preserving the site features.

Some questions in the survey of the form concern the typology of possible promotion of the Balzi Rossi as a geo-cultural site with the aim of improving safety conditions for the accessibility, both independently (52%) or through guided tours (43%). In this sense, the guided tours are preferred by a great majority of respondents (74%), respect than the realization of promotion material to be used by the

visitors without any further explanation. The respondents suggest as forms of visiting both cave tours (65%) or external tours (61%), and few of them (22%) also suggest how this could be feasible also from the sea, along the coast. The latter approach guarantees a panoramic view of the whole archaeological area. The combined visit to the Balzi Rossi museum and caves is the most suitable solution for the 91% of respondents.

The suggested methodologies of communication include panels or leaflets to support independent visiting to the site or through guided tours. Researchers underline also how additional multimedia products, like 3D virtual models,

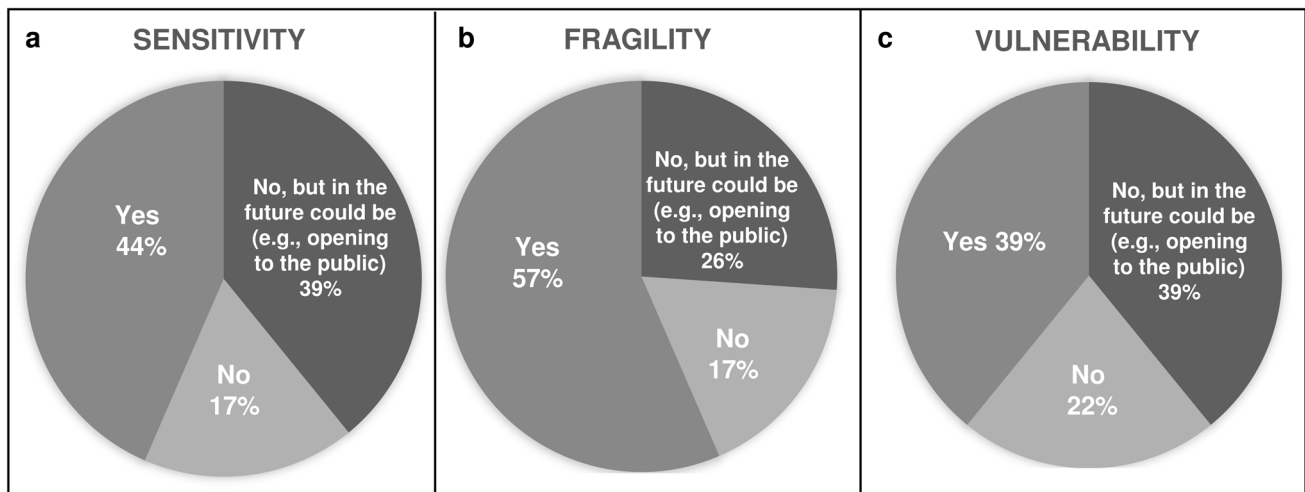


Fig. 10 The geoconservation features – Sensitivity (a), Fragility respect to intrinsic factors (b); Vulnerability respect to external factors (c)

available online and through the museum facilities (83%), and/or outdoor activities (biking, canoeing along set itineraries; 43.5%), may boost the promotion of site. Respect to on-foot itineraries, the biking and canoeing allow to connect sites in a relatively shorter time, along specific thematic trails. The cultural or geoheritage trails have to be appositely realized along existing paths or refurbished for the project. This also emerged from the answers to the open questions, in which some participants highlighted how the promotion of the Balzi Rossi site should be planned to widen the view to similar sites along the Liguro-Provençal coast, and in particular from Taggia to Nice (Fig. 1a). These trails should be also planned to include many features of the natural environment (83%). Another priority for tourism planning, according to 65% of respondents, is opportunities for disabled people.

Step 2: The Involvement of Local Communities and Stakeholders in Defining Geoconservation and Promotion Priorities

The topic of open discussion during the World Cafè activity (March the 2nd 2023; Fig. 11), was the importance of the Balzi Rossi site. After the first summary presentation on the peculiarities and the scientific relevance of the site, participants were split into three groups. The leader of each group collected the impressions of its members. First, the discussion was focused on the scientific importance of the site because it was not evident to some participants; indeed, most of them was not aware of the concept of geosite and its meaning in term of heritage (geology, geomorphology, archaeology, etc.). People generically know that this is a relevant prehistoric site, but they complain about its scarce visibility and the lack of engagement for tourists on offer

at the site. The common idea emerging is that the offer to tourists needs to be broadened besides the presence of a museum. The beauty of the landscape and the potential socio-economic relevance was strongly underlined by local touristic associations. Moreover, the discussion led to the greatest awareness in participants on the vulnerability and fragility of the site if not adequately managed.

The next topic discussed amongst the groups was promotion. Participants discussed new immersive technologies and the addition of more outdoor activities. Outdoor activities were especially considered since the participants belong mainly to tourism associations, boosting these kinds of promotion strategies. Among them, the planning of bike itineraries was evoked, suggesting to improve the existing cycling path network. In general, participants highlighted that the accessibility to the site should be improved.

Finally, the idea of applying to funding calls from the European Commission for boosting the local tourism emerged. From this meeting, a working group was set up to prepare the project, led by the Imperia Province, to apply to the NEB (New European Bauhaus) challenge call issued by the Liguria regional board. The NEB philosophy describes the features that, according to the European Commission (https://new-european-bauhaus.europa.eu/index_en), all the actions fostered by the European Union should have. Projects should, specifically, favor practices of promotion of beauty, sustainability, and inclusivity. In the case of cultural and environmental heritage, while highlighting its intrinsic beauty, projects should also promote the development of inclusive and sustainable activities. The proposed project “*ARCHEOblue&greenway: Paesaggi geoarcheologici del Ponente ligure*” (in English: *Geoarcheological landscapes in the Western Liguria*), classified first among the many proposals submitted to the NEB call. Its aims are: i) reinforcing



Fig. 11 The World Café activity – (a) The categories of participants to the activity; b, c, d Some moments of the presentation and of the discussions within and among groups

the ‘sense of place’ for citizens and communicating the natural and cultural heritage to tourists; ii) favouring the link and use of geocultural sites by different targets of users (young and senior citizens, fragile categories, tourists and generic public); iii) increasing the availability of services in the area to boost economic fallouts in the tourism sector, pushing forms of green tourism (biking, walking, public transportation); iv) improving the territorial governance for the integrated management of cultural and natural assets for a transboundary sustainable growth. The project collects also the ideas highlighted in the surveys about the possibility of reinforcing the connection between geocultural sites spread along the coastline of western Liguria, thus improving the territorial governance and cultural services in the area and strengthening the ‘sense of place’ in local population.

Discussion and Conclusions

The goal of the SPHeritage Project was to re-investigate the full potentiality of the Balzi Rossi archaeological area in a geoarchaeological perspective and applying modern Earth Sciences methods to increase the detail and precision of our

understanding of the paleoenvironmental evolution of the area (Pappalardo et al. 2023; Ryan et al. 2024). New scientific data obtained by researchers with different expertise and the huge work carried out by the members of the project to collect scientific publications on very different topics linked to the Balzi Rossi (Pappalardo et al. 2023) allow us to make a series of considerations in the perspective of promoting and enhancing the site, in collaboration with local entities. Indeed, the fresh approach proposed by the project aims at coupling the different features of the study area – the geological and cultural values – that have been considered as separate entities for decades.

The Liguria Region of Northern Italy belongs to a relevant cultural and natural heritage (Ferrando et al. 2021, 2023) and the Balzi Rossi site is catalogued as a geosite in the provincial, regional and national inventories. Ferrando et al. (2021) recognized the Balzi Rossi as a potential archaeogeosite (*sensu* Melelli et al. 2016), featured by high levels of integrity, interpretative potential, and accessibility, while a medium representativeness, rareness, scenic value, and secondary interest. However, the newly acquired results further underline the potential of Balzi Rossi not only as a geosite, but also as a geocultural site, where “the geological

features interact with cultural elements (historical or archaeological vestiges, cultural or religious monuments, etc.), and the geoheritage value joins the cultural value” (Reynard and Giusti 2018). Indeed, archaeological, paleontological, geological, geomorphological and paleoclimatic studies outlined the great scientific value of this area which testifies for the complex and long-lasting evolution of the human–environment system since the early days of the first settlements (Pappalardo et al. 2023; Ryan et al. 2024). The evidence of ancient human–environment interaction at the site, increases the rareness of Balzi Rossi respect to the previous evaluations present in literature. Moreover, the uniqueness as a speleological heritage site (*sensu* De Stefano Menin and de La Corte Bacci 2023) provides additional value to the site.

Another important point emerged from the survey with the scientists: the opportunity of connection with other prehistoric archaeological sites along the Liguro-Provençal coastal area, in Italy (e.g., Madonna dell’Arma; Fig. 1b), in France (e.g., Terra Amata, Vallonnet, Lazaret; Fig. 1b), and Monaco (e.g., Grotte de l’Observatoire; Fig. 1b). This could be informative on how settlement patterns of prehistoric human populations have been homogeneous within a physical region (Pappalardo 2022) extending beyond extant political/administrative boundaries (Del Lucchese and Starnini 2015b). Worth noting is that, of them, none of the 3 sites in the French territory (i.e., Terra Amata, Vallonnet, Lazaret), nor the Italian Madonna dell’Arma, are listed as geosites in the respective national inventories, as explained before for the French case.

Another interesting link could be with submerged geosites (e.g., Polla di Rovereto; Table 1). The submerged areas along coasts are interesting not only for their submerged morphology but also because they often retain traces of ancient settlements, initially built on land. Some of these sites are today considered geoheritage sites, where specific methodologies could be applied to assess their value (Rovere et al. 2010; Coratza et al. 2019; Fleury et al. 2023). In the case of the Balzi Rossi, the offshore submerged shelf, during periods of lowered sea level within the Pleistocene, became a coastal plain exploited by human groups looking for marine resources, being part of the Paleolithic archaeological landscape. The offshore record supports and increases the high scientific value of the area as it likely retains submerged sites of both archaeological and geomorphological value (e.g., Anthony et al. 2014; Sinuessa geosite, Campania Region, Coratza et al. 2021; the Mediterranean areas of Sigri, Greece, and Bergeggi, Liguria Region, Rovere et al. 2010).

Overall, interviewed researchers recognized the excellent to good qualities of Balzi Rossi as geocultural site, suggesting some potential strategies for sustainable promotion, like empowering multimedia products and setting multidisciplinary trails and outdoor activities to discover the site

according to the different targets of users (e.g., school students, amateurs, tourists, hikers, bikers), including disabled people.

More in detail, the Balzi Rossi Museum has a long tradition of teaching and educational activities, a solid base where experimenting with new immersive visions, innovative application of virtual tools for education and outreach activities (Diolaiuti et al. 2021) is possible. Augmented Reality, Mixed Reality and Virtual Reality are considered to have a great potential to improve the quality of an experience to discover cultural heritage (e.g., Innocente et al. 2023; Wisher et al. 2023) and the local Museum is nowadays experimenting such tools to improve the touristic experience (Iacono et al. 2024). To enhance the visitor’s experience, smartphone or tablet technologies could also allow the access to such contents via QR code (Diolaiuti et al. 2021).

The dissemination of scientific results, then, could be conveyed through specific thematic maps and cartography in a simplified form (e.g., Martin 2014; Bollati et al. 2017; Pelfini et al. 2020), available on the web or on site, in structures equipped with traditional and innovative tools (Pasquaré Mariotto and Venturini 2017).

Outdoor activities emerged as the preferred vehicle of promotion of the Balzi Rossi geocultural sites. Boat tours could, for instance, allow people to enjoy the spectacular coastal landscapes far from the coast, which, as in the case of the Balzi Rossi, show the complex of caves occupied by humans since thousands of year BP. Bicycle tourism, also in the form of E-biking and E-Mountain biking, provides an opportunity to explore and connect the areas, and it is an increasing trend in world tourism, as recently demonstrated by Senese et al. (2023). E-Biking is becoming even more common among the popular recreational activities as they allow even non-trained people to easily reach places relatively distant. As emerged also from the survey, a refurbishing of existing paths and the planning of new ones is needed to improve the accessibility to the Balzi Rossi site for hiking and biking.

The interaction with local community leaders and stakeholders is a fundamental starting point to plan promotion activities and to make them aware of their own heritage, cultural (e.g., strictly archaeological) or geocultural (Bollati et al. 2023). The World Cafè initiative was appreciated by the participants, representing a bridge between scientists, local administrations, economic entities, sport association and volunteers. The scientists brought information about the multifaceted scientific value of the site, whereas the local community leaders and stakeholders brought understanding of the needs of the local players involved in the promotion of tourism. The discussion among participants led finally to the agreed identification of different opportunities for the Balzi Rossi (and the potentially connected Liguro-Provençal sites). The successful application for the NEB award is then

a strong sign towards the enthusiasm and support of such kind of projects.

Concluding, the Balzi Rossi site is a feature of the geological and cultural heritage of the Liguro-Provençal coastal area (i.e., geocultural site), where the scientific information is of public interest, deserving to be shared with different types of audiences. The SPHeritage Project has thrown the seeds for setting new sustainable forms of promotion, based mainly on outdoor activities and Virtual Reality with the potential to connect the analogous sites located along the Liguro-Provençal coastal area to create a greater regional experience.

Acknowledgements We would like to thank all the institutions and people that supported our Balzi Rossi research, in particular the Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Imperia e Savona, the Direzione Regionale Musei Liguria, the Museo Preistorico dei Balzi Rossi e Area Archeologica, the Museo Civico di Sanremo, the Municipality of Sanremo, the Administration des Biens de SAS Le Prince de Monaco, and the Direction des Affaires Culturelles de Monaco. All research permits have been released by the Italian Ministry of Culture (MiC). This work was supported by the SPHeritage – “Lessons for the future from the heritage of the past” project (MUR grant number MUR FISR2019_00040, PI: M. Pappalardo). Additional support is from the Italian Ministry of University and Research (MUR) through the project “Dipartimenti di Eccellenza 2023–2027” awarded to the Dipartimento di Scienze della Terra “A. Desio” of the Università degli Studi di Milano (WP3).

Funding Open access funding provided by Università degli Studi di Milano within the CRUI-CARE Agreement.

Data Availability Data are available on request from the authors.

Declarations

Competing interests I declare the authors have no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

Anthony EJ, Marriner N, Morhange C (2014) Human influence and the changing geomorphology of Mediterranean deltas and coasts over the last 6000 years: from progradation to destruction phase? *Earth-Sci Rev* 139:336–361. <https://doi.org/10.1016/j.earscirev.2014.10.003>

- Barale L (2016) The early geological exploration of the Nice region (French Maritime Alps) in the late 18th–19th centuries. *P Geologist Assoc* 127(6):747–760. <https://doi.org/10.1016/j.pgeola.2016.11.010>
- Benazzi S, Slon V, Talamo S, Peresani M, Negrino F, Bailey SE, Sawyer S, Panetta D, Starnini E, Salvadori PA, Meyer M, Pääbo S, Hublin JJ (2015) The makers of the Protoaurignacian and implications for Neandertal extinction. *Science* 348(6236):793–796. <https://doi.org/10.1126/science.aaa2773>
- Bollati IM, Zerboni A (2021) The Po Plain loess basin (northern Italy): scientific values, threats, and promotion opportunities. *Geoheritage* 13(3):74. <https://doi.org/10.1007/s12371-021-00596-2>
- Bollati I, Crosa Lenz B, 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). *J Mt Sci* 14(6):1023–1038. <https://doi.org/10.1007/s11629-017-4427-7>
- Bollati IM, Caironi V, Alessio G, Muccignato E, Pelfini M, Bagnati T (2023) How to integrate cultural and geological heritage? The case of the Comuniterrae project (Sesia Val Grande UNESCO Global Geopark, northern Italy). *AUC Geogr* 58(1):129–145. <https://doi.org/10.14712/23361980.2023.10>
- Brancucci G, Paliaga G (2008) *Atlante dei geositi della Liguria: guida alla lettura del paesaggio geomorfologico ligure* (No. 7). Centro Stampa Offset
- Brandolini F, Pelfini M, Cremaschi M (2019) Estimating the potential of archaeo-historical data in the definition of geomorphosites and geoeducational itineraries in the Central Po Plain (N Italy). *Geoheritage* 11:1371–1396. <https://doi.org/10.1007/s12371-019-00370-5>
- Brilha J (2018) Geoheritage: inventories and evaluation. In Reynard E, Brilha J (eds) *Geoheritage*. Elsevier, Amsterdam, pp 69–85. <https://doi.org/10.1016/B978-0-12-809531-7.00004-6>
- Candida L (1959) L'escursione 1959 della Società Geografica Italiana (Riviera di Ponente e Provenza meridionale). *Boll Soc Geogr Ital* 23:345–375
- Coratza P, Vandelli V, Fiorentini L, Paliaga G, Faccini F (2019) Bridging terrestrial and marine geoheritage: assessing geosites in Portofino Natural Park (Italy). *Water* 11:2112. <https://doi.org/10.3390/w11102112>
- Coratza P, Bollati IM, Panizza V, Brandolini P, Castaldini D, Cucchi F, Deiana G, Del Monte M, Faccini F, Finocchiaro F, Gioia D, Melis R, Minopoli C, Nesci O, Paliaga G, Pennetta M, Perotti L, Pica A, Tognetto F, Trocciola A, Valentini L, Giardino M, Pelfini M (2021) Advances in geoheritage mapping: application to iconic geomorphological examples from the Italian landscape. *Sustainability* 13:11538. <https://doi.org/10.3390/su132011538>
- Costanzo S, Pappalardo M, Starnini E, Rossoni-Notter E, Notter O, Moussous A, Soares-Remiseiro M, Fermo P, Cremaschi M, Zerboni A (2024) Integrating musealized archaeological sediment collections into current geoarchaeological analytical frameworks for sustainable research practices. *MethodsX* 13(2024):102897. <https://doi.org/10.1016/j.mex.2024.102897>
- Dallagiovanna G, Fanucci F, Pellegrini L, Seno S, Bonini L, Decarlis A, Maino M, Morelli D, Toscani G (2017) - Note illustrative della Carta Geologica d'Italia alla scala 1:50.000, Foglio 257 e 270 Dolceacqua-Ventimiglia, ISPRA, Italy, pp 76
- De Stefano Menin D, de La Corte Bacci D (2023) Qualification of caves for educational use and scientific dissemination: a methodological proposal. *Geoheritage* 15:29. <https://doi.org/10.1007/s12371-023-00789-x>
- De Lumley H, Khatib S, Echassoux A, Todisco D (2001) Les lignes de rivage quaternaire en relation avec les sites paléolithiques des Alpes-Maritimes et de la Ligurie occidentale. *Archeosci Rev D'archéométrie* 25(1):125–134
- Del Lucchese A, Starnini E (2015a) Museo Preistorico dei Balzi Rossi e area archeologica delle grotte. Rete dei Musei e delle

- aree archeologiche della Liguria, Progetto Accessit Interreg Marittimo-IT FR-Maritime, Regione Liguria
- Del Lucchese A, Starnini E (2015b) Il progetto europeo “Accessit”. *Archeologia in Liguria*, vol. V, nuova serie, 2012–2013, Genova, Sagep, pp 261–262
- Del Lucchese A (1996) Museo Preistorico dei Balzi Rossi. Ventimiglia, Itinerari musei, gallerie, scavi, monumenti, n.s., Istituto Poligrafico dello Stato
- Diolaiuti G, Maugeri M, Senese A, Panizza M, Ambrosini R, Ficeola GF, Parolini M, Fugazza D, Traversa G, Scaccia D, Franceschini M, Citron L, Pelfini M (2021) Immersive and virtual tools to see and understand climate change impacts on glaciers: a new challenge for scientific dissemination and inclusive education. *Geogr Fis Dinam Quat* 44(1):67–77. <https://doi.org/10.4461/GFDQ.2021.44.6>
- Federici PR, Pappalardo M (2006) Evidence of Marine Isotope Stage 5 highstand in Liguria (Italy) and its tectonic significance. *Quater Int* 145–146:68–77. <https://doi.org/10.1016/j.quaint.2005.07.003>
- Ferrando A, Faccini F, Poggi F, Coratza P (2021) Geosites inventory in Liguria region (Northern Italy): a tool for regional geoconservation and environmental management. *Sustainability* 13(4):2346. <https://doi.org/10.3390/su13042346>
- Ferrando A, Faccini F, Paliaga G, Coratza P (2023) Geosites and geological landscapes of Liguria (Italy). *J Maps* 19(1):2145919. <https://doi.org/10.1080/17445647.2022.2145919>
- Fleury P, Pistre S, Bakalowicz M (2023) Coastal karst aquifers and submarine springs: what future for their water resources? *Comptes Rendus Géosci* 355(S1):487–500. <https://doi.org/10.5802/crgeos.168>
- Fouache E, Rasse M (2009) Archaeology, geoarchaeology and geomorphosite management: towards a typology of geoarchaeosites. In: Reynard E, Coratza P, Regolini-Bissig G (eds) *Geomorphosites*. Pfeil, München, pp 213–223
- Fouache E, Ecochard E, Kuzucuoğlu C, Carcaud Ekmemekçi M, Ulusoy I, Çiner A, Des Courtis J (2012) Palaeogeographical reconstruction and management challenges of an archaeological site by UNESCO: the case of the Letoon shrine in the Plain (Turkey). *Quaest Geogr* 31(1):37–49. <https://doi.org/10.2478/v10117-012-0002-z>
- García-Ortiz E, Fuertes-Gutiérrez I, Fernández-Martínez E (2014) Concepts and terminology for the risk of degradation of geological heritage sites: fragility and natural vulnerability, a case study. *P Geologist Assoc* 125(4):463–479. <https://doi.org/10.1016/j.pgeola.2014.06.003>
- Gray M (2004) *Geodiversity: valuing and conserving abiotic nature*. Wiley, Chichester
- Gray M, Gordon JE, Brown EJ (2013) Geodiversity and the ecosystem approach: the contribution of geoscience in delivering integrated environmental management. *P Geologist Assoc* 124(4):659–673. <https://doi.org/10.1016/j.pgeola.2013.01.003>
- Iacono S, Scaramuzzino M, Martini L, Panelli C, Zolezzi D, Perotti M, Traverso A, Vercelli GV (2024) Virtual reality in cultural heritage: a setup for Balzi Rossi Museum. *Appl Sci* 14(9):3562. <https://doi.org/10.3390/app14093562>
- Innocente A, Ulrich L, Moos S, Vezzetti E (2023) A framework study on the use of immersive XR technologies in the cultural heritage domain. *J Cult Herit* 62:268–284. <https://doi.org/10.1016/j.culher.2023.06.001>
- Isetti G, De Lumley H, Miskowsky (1962) Il giacimento musteriense della grotta dell’Arma presso Bussana (Sanremo). *Riv Stud Liguri* XXVIII:1–4 (1)
- Lahmidi S, Lagnaoui A, Adnani AE, Berrada I, Saadi M, Bahaj T (2022) Integrating geological and archaeological heritage for conservation and promotion of Fom Larjamme Geosite from Bani Geopark Project South-Eastern Morocco. *Geoheritage* 14(3):1–20. <https://doi.org/10.1007/s12371-022-00718-4>
- Marescotti P, Castello G, Briguglio A, Caprioglio MC, Crispini L, Firpo M (2022) Geosite assessment in the Beigua UNESCO global geopark (Liguria, Italy): a case study in linking geoheritage with education, tourism, and community involvement. *Land* 11:1667. <https://doi.org/10.3390/land11101667>
- Martin S (2014) Interactive visual media for geomorphological heritage interpretation. Theoretical approach and examples. *Geoheritage* 6(2):149–157. <https://doi.org/10.1007/s12371-014-0107-y>
- Melelli L, Bizzarri R, Baldanza A, Gregori L (2016) The etruscan “Volumni Hypogeum” archeo-geosite: new sedimentological and geomorphological insights on the tombal complex. *Geoheritage* 8:301–314. <https://doi.org/10.1007/s12371-015-0162-z>
- Niculita M, Mărgărint MC (2018) Landslides and fortified settlements as valuable cultural geomorphosites and geoheritage sites in the Moldavian Plateau. *Geoheritage* 10(4):613–634. <https://doi.org/10.1007/s12371-017-0261-0>
- Panizza M, Piacente S (2003) *Geomorfologia culturale*, Pitagora Ed., Bologna
- Pappalardo M, Zerboni A, Notter O, Rossoni-Notter E, Negrino F, Ryan DD, Starnini E, Vacchi M, Bollati I, Forti L, Moussous A, Muttoni G, Gazzo S, Pelfini M, Perego A, Perini S, Pezzotta A, Proietto A, Serradimigni M, Ragaini L, Regattieri E, Rovere A (2023) SP Heritage: un progetto di ricerca per lo studio dei cambiamenti ambientali del passato attraverso il patrimonio culturale. *Bull Mus Anthropol Préhist Monaco* 61:181–195
- Pappalardo M (2022) Regione fisica, naturale, ambientale. In: Gavinelli D, Bolocan Goldstein M (eds) *Regioni e regionalizzazione. Lo spazio-mondo in divenire*. Pearson Milano-Torino, pp 40–56
- Pasquaré Mariotto F, Venturini C (2017) Strategies and tools for improving Earth Science education and popularization in museums. *Geoheritage* 9(2):187–194. <https://doi.org/10.1007/s12371-016-0194-z>
- Pelfini M, Bollati I (2014) Landforms and geomorphosites ongoing changes: concepts and implications for geoheritage promotion. *Quaest Geogr* 33(1):131–143. <https://doi.org/10.2478/quageo-2014-0009>
- Pelfini M, Brandolini F, D’Archi S, Pellegrini L, Bollati I (2020) Pavia civitas gloriosa: urban geomorphology for a thematic itinerary on geocultural heritage in Pavia (Central Po Plain, N Italy). *J Maps* 17(4):42–50. <https://doi.org/10.1080/17445647.2020.1736198>
- Pijet-Migoñ E, Migoñ P (2022) Geoheritage and cultural heritage — a review of recurrent and interlinked themes. *Geosciences* 12(2):98. <https://doi.org/10.3390/geosciences12020098>
- Prosser CD, Burek CV, Evans DH, Gordon JE, Kirkbride VB, Rennie AF, Walmsley CS (2010) Conserving geodiversity sites in a changing climate: management challenges and responses. *Geoheritage* 2(3):123–136. <https://doi.org/10.1007/s12371-010-0016-7>
- Reynard E, Giusti C (2018) The landscape and the cultural value of geoheritage. In: Reynard E, Brilha J (eds) *Geoheritage*. Elsevier Ed, pp 147–166. <https://doi.org/10.1016/B978-0-12-809531-7.00008-3>
- Rovere A, Vacchi M, Parravicini V, Morri C, Bianchi CN, Firpo M, Europa C (2010) Bringing geoheritage underwater: methodological approaches to evaluation and mapping. *Mapping geoheritage, Géovisions*, 35
- Ryan DD, Starnini E, Serradimigni M, Rossoni-Notter E, Notter O, Zerboni A, Negrino F, Grimaldi S, Vacchi M, Ragaini L, Rovere A, Perego A, Muttoni G, Santaniello F, Moussou A, Pappalardo M (2024) A geoarchaeological review of Balzi Rossi, Italy: a crossroad of Palaeolithic populations in the northwest Mediterranean. *Quat Sci Rev* 327:108515. <https://doi.org/10.1016/j.quascirev.2024.108515>
- Senese A, Pelfini M, Maragno D, Bollati IM, Fugazza D, Vaghi L, Federici M, Grimaldi L, Belotti P, Lauri P, Ferliga C, La Rocca L, Diolaiuti GA (2023) The role of e-bike in discovering geodiversity and geoheritage. *Sustainability* 15(6):4979. <https://doi.org/10.3390/su15064979>
- Simone S (1968–1969) Les formations de la mer du Mindel Riss et les brèches à ossements rissiennes de la Grotte du Prince Grimaldi, Ligurie italienne. *Bulletin du Musée d’Anthropologie Préhistorique de Monaco* 15:5–90

- Villeneuve LDe, Boule M, Verneau R, Cartailhac E (1906–1912) *Les Grottes de Grimaldi*, vol 2. Imprimerie de Monaco, Monaco
- Wisher I, Pettitt P, Kentridge R (2023) The deep past in the virtual present: developing an interdisciplinary approach towards understanding the psychological foundations of palaeolithic cave art. *Sci Rep* 13:19009. <https://doi.org/10.1038/s41598-023-46320-8>
- Yokoama Y (1989) Direct gamma-ray spectrometric dating of Anteneandertalian and Neandertalian human remains. *Proceedings of the*

Second International Congress of Human Palaeontology, Turin, September 28–October 3, 1987, Jaca Book Ed., pp 387–390

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.