Geoheritage encompasses the valuable and significant geological and geomorphological elements of the landscape worthy of conservation (geosites): it is an important component of natural heritage and it often constitutes the ‘skeleton’ of the landscape (Reynard, Coratza, & Hobléa, 2016a; Serrano & Gonzalez Trueba, 2011). Due to its scientific, social and economic implications, geoheritage aroused a strong interest within the scientific community, as shown by the vast amount of scientific literature in the field of geoheritage identification, assessment, promotion and management (cf. Brilha, 2017; Coratza & Hobléa, 2017 and reference therein; Gray, 2017).

At an international level, there is currently a great variety of thematic maps concerning geoheritage; since a single universally recognised legend is yet to be implemented, the maps can be very different, depending on aim, scale and target users (cf. Carton, Coratza, & Marchetti, 2005; Coratza & Regolini-Bissig, 2009). Recently, there has been new interest in geoheritage, as shown by the works of several authors, particularly in Europe, mainly in the field of geoheritage promotion (Bertacchini, Benito, & Castaldini, 2007; Bissig, 2008; Brandolini, Faccini, Robbiani, & Bulgarelli, 2011; Castaldini, Valdati, Ilies, & Chiriac, 2005; Fuertes-Gutiérrez & Fernández-Martínez, 2012; Martínez-Graña, Goy Y Goy, & Cardeña, 2011; Orrù & Panizza, 2009; Regolini, 2012; Rovere, Vacchi, Parravicini, Bianchi, & Firpo, 2010; Zwoliński & Stachowiak, 2012).

Protected areas represent open-air laboratories where the conservation of geoheritage – and more in general of natural heritage – and its promotion through initiatives of public use (e.g. geotourism products, excursion and educational trails with panels, etc.) are the main objectives. For protected areas, a geoheritage map can represent a very useful tool for local authorities and geopark managers both for management and promotion purposes. This paper introduces a novel Geoheritage Map of the Portofino Natural Park (Italy) in the Eastern Riviera of Liguria (Figure 1). The protected area is internationally well known for its unique landscape and the natural, artistic and cultural values (Balletti & Soppa, 2015) and it recently became National Park. The map, which was produced in strict collaboration with the park managers, provides information about the geosites of the park and other features of interest (e.g. botanical, historical, archaeological elements, etc.). With appropriate integrations and simplifications, this map can be used to produce applied-derived maps like geotourism and geohazard maps for tourists and visitors and maps of the vulnerability of geosites due to both natural and human processes.
2. General settings

The Park of Portofino protects the Portofino Peninsula, located c. 18 km E of Genova, for a total surface of 1056.26 ha, of which 58.61 ha is a full protection area (5.5%), 362.50 ha is an area of protection (34.3%) and 37.84 ha is a development area (3.6%). A contiguous protected area of additional 932 ha adjoins the park.

The Park includes the municipalities of Camogli, Portofino and Santa Margherita Ligure; the frame area comprises Rapallo, Zoagli and Chiavari. The total resident population of the park is just over 750 inhabitants.

Due to its landscape and the natural and cultural values, the Portofino Peninsula has been a protected area for more than 80 years (Law n°1251/1935): since 1995, it has been managed by the Ente Parco Portofino Authority (Regional Law n° 12/1995), which redrew the boundaries of the park (Regional Law n° 29/2001). Subsequently, the Portofino Protected Marine Area was created by an Environment Ministry Decree dated 26/04/1999, implementing Law n°979/1982. Recently, the new Law n° 394/91 instituted the National Park of Portofino, which includes both the continental and the marine sectors.

The Portofino Peninsula covers 18 km² and has a 13 km long coastline; the orography is characterised by a mountain ridge with different elevations including Mt. Tocco (543 m), Mt. di Portofino (610 m), Mt. delle Bocche (506 m) and Mt. Pollone (472 m): this promontory breaks the continuity of the coast between Genoa and La Spezia.

The climate of Mt. di Portofino is Mediterranean, Csa according to Köppen, with hot summers, long periods of insolation, mild winters and rainy autumns (Sacchini, Ferraris, Faccini, & Firpo, 2012). At a local scale, different microclimates are conditioned by elevation, slope aspects and land use: this is particularly common along the southern side, usually hot and dry, where some short and narrow valleys have a humid and cool climate even in the middle of the summer, with high thermal excursion.

The park is an internationally acknowledged area of great landscape value for its historical settlements, vegetation and geomorphological features. The first villages date back to Roman times; in the Middle Ages several important religious buildings were established (e.g. San Fruttuoso, Cervara, Niasca and San Nicolò), linked by historical trails which are still in use. Due to the coexistence of Mediterranean, continental and mesophilic species, the vegetation of the park is of great interest. Terraces for agriculture, sustained by dry stone walls, constitute the most representative element of traditional human landscape of the park.

The geomorphological dynamic is primarily shaped by gravity, water and wave motion, although geomorphological processes due to karstic phenomena, periglacial deposits and anthropic landforms are also found. Among the coastal landforms, the almost vertical conglomerate cliffs of the southern side of the promontory, more than 200 m high, are almost unique in the Mediterranean.
3. Material and methods

The workflow in **Figure 2** summarises the different steps of the methodological process.

Firstly, thematic maps and scientiﬁc publications on the geology and geomorphology of the Park were gathered as well as aerial photographs and digital orthophotographs; these were interpreted and integrated with fresh data from detailed ﬁeld surveys. This process facilitated the identiﬁcation of the principal abiotic features and tourist information of the area, which have been organised and implemented in a spatial geodatabase using a GIS (ArcGIS) software. In addition, a speciﬁc base map was realised for the purpose of this study: thematic layers such as isohyets, roads, buildings, trails and so on were overlaid on a Digital Terrain Model (res. 5 m).

Based on the information gathered in this ﬁrst phase of the process, the geoheritage map was produced: the map has different levels of reading and four speciﬁc themes are shown in detail:

- **Geological and geomorphological features**: geological and geomorphological data including landforms, deposits and geological elements obtained both from ﬁeld surveys, ofﬁcial geological cartography and vector maps produced in specific studies of urban spatial planning (Autorità di bacino regionale, 2015; Boni et al., 1969; Servizio Geologico d’Italia, 1968).
- **Geosites**: following a series of ﬁeld surveys, sites of geological interest have been selected and classiﬁed according to their main scientiﬁc relevance in: geological, geomorphological, mineralogical-petrographical, hydrogeological and viewpoints (sensu Migoni & Pijet-Migoni, 2017). The signiﬁcance of geological elements was evaluated using the following criteria: intrinsic value; accessibility; state of conservation; visual impact; rarity; chronological and territorial distribution. All the geosites were identiﬁed, mapped and described according to the ‘Italian geosites inventory method’ and the data were collected into an easily updatable, interactive and ﬂexible database.
- **Natural and cultural features**: sites of tourist interest, including archaeological sites, historical buildings, terraced landscapes, artiﬁcial cavities and sites of botanical and ecological interest have been selected. The sites show the complex relationships between the unique and outstanding geological, biological and human heritage of the Portofino park.
- **Trails and path features**: the map contains information on trails and footpaths, extracted from both the existing vector data and the archival information held by the Park of Portofino. The footpaths were classiﬁed according to their diﬃculty level (tourist, hiker, expert hiker, only with guide); two geo-touristic itineraries of the Park of Portofino were added as well (‘Le Vie del Conglomerato’).

4. Results: geoheritage map

4.1. Geological and geomorphological data

The geology of the Portofino Natural Park is characterised by the Conglomerate of Portofino (Conglomerato di Portofino) along the southern slope, while the marly limestone Flysch of Mt Antola (Calcari del Monte Antola) outcrops in its Northern part (Figure 3). Today, the contact between these formations is considered a partial tectonic lineation which joins them with a WNW–ESE direction (Faccini, Benedettini, Pelﬁni, & Brandolini, 2014).

The Conglomerate of Portofino is characterised by clasts of marly limestone of centimetric or metric size and secondarily by sandstone: other lythotypes such as ophiolites, limestones, cherts, gneiss and schysts are less frequent (Brandolini, Canepa, Faccini, Robbiano, & Terranova, 2007; Corsi, Elter, & Giammarino, 2001; Marini, 1981). The structural settings of the Flysch are related to several deformative events, both brittle and ductile; the outcrop level...
shows mainly isoclinal folds with vergence towards SSW and axe-oriented WNW–ESE.

The southern and western part of the Promontory is characterised by high rocky cliffs, shaped by the sea wave action. The active cliffs are from 25 to 50 high, and occasionally >50 m high in Punta del Buco, Punta Carega and Vitrale. Their mean gradient ranges between 45° and 65°, but some vertical cliffs are found as well, as like as some sectors with a gradient of 30°.

Some debris and rock falls are observed mainly along the southern slopes where the cliffs show heights >10 m: these were shaped by gravity as in the case of the rocky cliffs in the areas S of Mt. Tocco, in the eastern side of the Bay of San Fruttuoso, at Cala del Prato and Vitrale. Scars are visible along the area located W of the ridge between Mt. Tocco and Mt. di Portofino: this is the activation surface of some well-known landslides located between San Rocco, Mortola and San Nicolò (Brando-lini, Faccini, Robbiano, & Terranova, 2007).

Loose and thin covers are spread over the whole territory, often remodelled to build terraces with dry stone walls. Colluvial deposits are found along the rivers such as in Paraggi and San Fruttuoso (Faccini, Piccazzo, & Robbiano, 2008).

Some landslides are historically known and have been active in recent times, such as in Gave, and they can constitute a potential risk for human settlements and hikers.

Due to the steepness of riverbeds and the thickness of loose debris, debris flows can be triggered after short and heavy rainfall events. In the past, these have already caused casualties and damages to buildings (Faccini, Piccazzo, & Robbiano, 2009).

Natural caves, mainly generated by tectonic shifts and secondarily by processes of physical–chemical dissolution were mapped.

4.2. Geosites

The Portofino Park shows a great variety of geosites that have been selected according to their scientific interest as geological, geomorphological, mineralogical-petrographical, hydrogeological and viewpoints (Figure 4).

The sites of geological interest are mainly related to characteristic rocky outcrops which illustrate the geological history of the area. These are: the Conglomerate outcrops located in Pietre Strette, Punta Chiappa and along the footpath between the San Giorgio Church and the Lighthouse of Portofino (Faccini, Piccazzo, Robbiano, & Roccati, 2008); the Flysch of Mt. Antola which shows its characteristic folded layers both along the western cliffs of the promontory and along the eastern side, by Punta Pedale.
Different examples of geomorphosites are found in the area of the park. For their singularity and high scientific value, landforms due to gravity and to coastal processes are the most representative geomorphosites of the park. Among the most interesting examples are the high rocky cliffs of the southern side, the huge boulders of Pietre Strette, the stacks spread along the coastline between Punta Pedale and the Castle of Paraggi (Faccini et al., 2014) and the lateral spread phenomena of the Conglomerate which are visible in Mt. Tocco, Mt. Pollone and Mt. Croci di Nozarego.

The most significant mineralogical-petrographical examples are the clasts of anagenites along the footpath between Caselle and Pietre Strette, the stacks spread along the coastline between Punta Pedale and the Castle of Paraggi (Faccini et al., 2014) and the lateral spread phenomena of the Conglomerate which are visible in Mt. Tocco, Mt. Pollone and Mt. Croci di Nozarego.

Some viewpoints are listed as viewpoint geosites, sensu Migoń and Pijet-Migoń (2017), described as ‘localities which offer a wider look at the surrounding landscape and hence, better understanding of its history’ (Migoń & Pijet-Migoń, 2017). This category includes the conglomerate pinnacles in Batterie, Sella di Toca, Base O, Mt. Campana and Semaforo Nuovo, while the landscape shaped by the Flysch of Mt. Antola can be observed in the western side of the Promontory (San Rocco) and in Sotto le Gave in the eastern side.

Hydrogeological sites include several springs located both along the fractures of the Conglomerate and along the contact with the Flysch of Mt. Antola; many water intake structures have a geoheritage value due to the historical underground tunnels such as Coppelli, Acquaviva and Caselle (Bonaria, Faccini, Galiano, & Sacchini, 2016).

Figure 4. Geosites of the Portofino Park: (a) folds in marly limestones Flysch (see geosites list n. 3 in the Main Map), photo by A. Girani; (b) Mt. Campana from the Batterie geo-viewpoint, photo by F. Faccini (n. 35); (c) high rocky cliffs, photo by A. Girani (n. 10); (d) conglomerates, photo by A. Girani; (e) coal interlayers in conglomerate, photo by B. Mortola (n. 13); (f) Caselle spring, photo by F. Faccini (n. 18).
4.3. Natural and cultural features

The unique geological and geomorphological features of the Portofino Natural Park are associated with botanical, historical and archaeological elements of regional significance.

Particular habitats such as the wetlands of Cala dell’Oro, Vessinaro, Rio Gentile and the Acquaviva Valley where ferns like *Osmunda regalis* are found, have an important ecological value. Some rare rocky species (*Saxifraga cochlearis* e *Limonium cordatum*) can be found in the Conglomerate rocks of the Promontory.

Archaeological sites are significant heritage elements too (*Delfino, Faccini, & Firpo, 2008; De Vingo, 2012*): the most remarkable ones are the medieval settlement of San Fruttuoso, the Neolithic site of Castellaro of Camogli (where a landslide occurred in the Bronze Age).
Age is documented) and the Cave of Eremita, which shows important historical-environmental elements.

The historical buildings of the Mt. di Portofino are mainly religious structures which represent important examples of stone-built cultural heritage (Dufour Bozzo, Cavana, & Calcagno, 2010). The Abbey of San Fruttuoso and the complex of San Nicolò are particularly significant. Other important buildings are the mills along the Acquaviva Brook with their mill canals and the sixteenth-century watchtowers spread along the coast.

Cultivated terraces are today recognised as an example of cultural landscape and the product of the interaction between geomorphological dynamics and human-made landforms (Van Der Sluis, Kizos, & Pedroli, 2014): some interesting terraced areas are found in the park, including the ones in San Fruttuoso, Prato, Sant’Anna and Galletti (Paliaga, Giostrella, & Faccini, 2016).

The Park also has some artificial cavities characterised by geological and cultural values such as the tunnels of the Via dei Tubi, the military tunnels of Le Batterie and the access tunnels to some properties in Portofino (Figure 5).

### 4.4. Path and trail features

The Park of Portofino is characterised by a dense network of trails for a total length of 80 km; the main gateways of the Park are San Rocco di Camogli, Portofino, Santa Margherita Ligure, Portofino Vetta and, from the sea, San Fruttuoso.

The footpaths are diverse and characterised by different lengths, difficulty levels and technical features. The trail network covers different morphological and topo-climatic contexts from the sea level up to 610 m asl on the top of Mt. di Portofino, with slopes up to >100%: unpaved footpaths are the most frequent ones, but there are also paved stretches (concrete and dirt roads), steep staircases, exposed stretches on rock secured with chains and trails only suitable to expert hikers (Brandolini, Faccini, & Piccazzo, 2006).

There are two geothematic footpaths with numbered stops illustrating the geodiversity of the Conglomerate of Portofino: they are located in Punta Chiappa and between Gaixella and Felciara.

The number of accesses to the trail network of the Park of Portofino was monitored by using a series of eco-counters: this system was activated by the Park in 2006 in Pietre Strette and enlarged in 2009 with new monitoring stations in Fornelli, Via dei Tubi, Caselle, Passo del Bacio, Base O, Prato and Mulini (Figure 6): transit through Pietre Strette raised from >73,000 passages/year in 2010 to 90,000 passages/year in 2011, with peaks of c. 1500 passages/day. More than 1000 passages/day were registered in Pietre Strette, Fornelli and
Mulini and except for the Via dei Tubi in the remaining areas peaks >500 passages/day were registered.

The visits are spread all year around for a total amount of >100,000 hikers: however, their frequency is variable. A peak is registered in May (mostly because of school trips, >11,000 visits), while the minimum number of visitors is in November and February, with c. 4500 hikers/month.

Outdoor activities have significantly grown over the last decades and today the area is increasingly visited throughout the year.

Despite a consolidated public awareness policy promoted by the Park, several accidents involving tourists and hikers are reported. The characteristics of the trail network and the geographical features of the territory make it necessary to wear appropriate mountain clothing and to be in good physical conditions. For this purpose, a statistic survey was carried out based on the rescue operations by the Italian Alpine and Speleological Rescue Corp between 1999 and 2015 (Figure 7): an average number of >5 rescues/year is recorded, with a maximum value of 10 (2015) and a minimum of 2 (2001). The record data are too short to allow an assessment of statistical significance, but it underlines a growing number of accidents.

Adults between 31 and 65 years old are the most common age group: the rescues are spread throughout the week but the modal value shows that they prevail on Sundays and Fridays. The rescue operations occur in every month with higher concentrations between May and September in accordance with the number of visits recorded along the trails. The rescues mainly involved the footpath along an area W of San Fruttuoso called Passo del Bacio.

**5. Conclusion and research perspective**

Due to its potential high environmental impact, the growing demand of outdoor tourism constitutes a challenge for protected areas. The correct identification and knowledge of the landscape features and potential natural hazard can help to reduce the risk and the impact of tourism (Faccini, Roccati, & Firpo, 2012; Lambiel, Maillard, Kummert, & Reynard, 2016). In this sense, thematic maps can be considered efficient tools to inform about geological and geomorphological landscape. The same map summarise the geological and geomorphological settings of an area, its geoheritage elements and potential natural hazards.

The Geoheritage map discussed in this paper is a novel product for the Portofino Park and can provide new insights into the appropriate management, conservation and enhancement of the landscape values of this outstanding territory (Reynard & Coratza, 2016; Figure 7).
Reynard, Coratza, & Regolini-Bissig, 2009). Accurate studies and researches make it possible to develop new strategies of spatial planning and management of the territory which directly involves the local communities. Due to the physical-geographical and geomorphological features of the park, some of the most challenging trails can pose a visitor safety issue: in the southern part, three trails that lead to San Fruttuoso develop through steep scarps and rocky valleys. The number of accidents occurred between Batterie and San Fruttuoso is still very high; therefore, risk mitigation strategies are necessary, including an information and education campaign on geology and environment. For this purpose, a detailed geo-hiking map will facilitate the simple yet rigorous communication of information about natural hazards associated with the geomorphological dynamics and meteoclimatic phenomena of the trail network.

Software

ArcGIS was used for the production of the geoheritage map, Adobe Reader and Microsoft Excel were used respectively for the related legend and for the diagrams and histograms.

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