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The Inventory and Quantitative Assessment of Geodiversity as Strategic Tools for Promoting Sustainable Geoconservation and Geo-Education in the Peloritani Mountains (Italy)

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Abstract: Most methods used for geoheritage inventories do not consider the quantitative assessment of the geodiversity indicators; consequently, it can happen that some geosites are wrongly inventoried as geodiversity sites and vice versa or activities for scientific, educational, and touristic purposes actually should not be planned in geoheritage sites unprovided with requirements. The main aim of the present paper is to raise awareness of the type of geoheritage present in sixteen localities of the Calabria–Peloritani Arc (Messina province; Italy) and suitable for scientific/educational/touristic assets. The main results of the research may be synthesized as follows: (i) identification of several potential geosites of international significance; (ii) exclusion of several geosites from any possible educational and touristic initiatives; (iii) possibility to promote educational initiatives among a broader public in some geosites and geodiversity sites, best addressed to postgraduate geology students in structural geology, tectonics, and stratigraphy, and/or PhD students or young researchers; (iv) planning of a geo route devoted to the geoknowledge transfer on Alpine thrust tectonics and Miocene block rotations involving arc-like structures such as the Calabria–Peloritani Arc and Paleozoic to Meso-Cenozoic stratigraphy.

Keywords: geology; geoheritage; geodiversity; geoconservation; inventory; quantitative assessment; scientific value; educational use; touristic use; degradation risk

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1. Introduction

Geodiversity is the most generic term in the topic of geological heritage and is considered to be the geological equivalent of biodiversity [1]. Geoheritage refers to geodiversity elements in a given place [2], whereas the term geosite was initially defined as a geoheritage site with scientific, historical, and cultural heritage interest, accessible for visits and studies, and internationally well-known [3]. Geoconservation has to identify, protect, and adequately manage significant natural elements of the geodiversity [4]. Geoconservation is paramount for geologists as geodiversity is vital for supporting the prosecution of geological research and geo-education. All these geodiversity concepts are closely related and strongly evolved in their original definition, especially in the last decade [1–54].

According to Brilha (2016) [37] geodiversity includes more specific concepts such as geosites, geoheritage elements, geodiversity sites, and geodiversity elements (Figure 1) related to the selection, preservation, and protection of the geological heritage. A geosite is defined as a site showing geodiversity elements (fossils, minerals, rocks, sedimentary successions, folds, faults, soils, waters) provided with high scientific value/relevance as representative of the Earth's history and evolution. The geological framework represents the main topic related to the geological materials and processes that may allow reconstructing the geological history of a particular area; the framework may be represented by different potential geosites [37]. Geodiversity sites may present local, national, and international relevance and this concept replaces the old RIGS (Regionally Important Geological/Geomorphological Sites [16,20]). Geodiversity sites have relevant educational and touristic value and no significant scientific value [37].

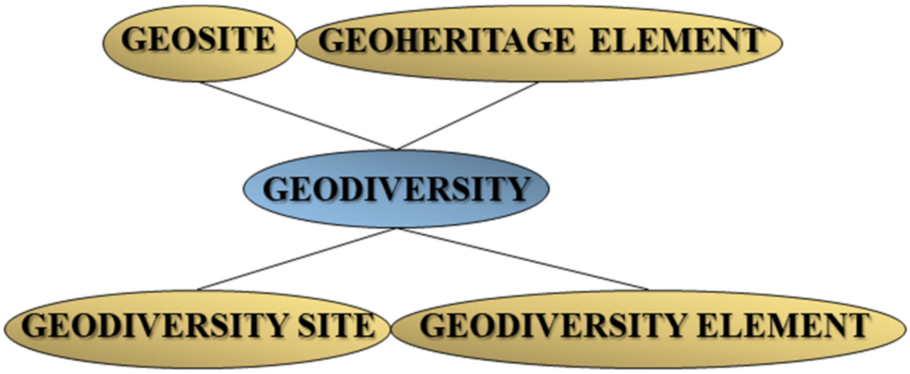

Figure 1. The geodiversity concept includes geosites, geoheritage elements, geodiversity sites, and geodiversity elements.

Sites showing geodiversity and analyzed to reconstruct the geological and geomorphological evolution must be protected for future generations of geologists to be able to continue the scientific research. The preservation requirement of the natural heritage is essential for the improvement of earth sciences and the knowledge of the planet. Preservation is necessary because of the risk of deterioration or destruction of the geological heritage primarily due to anthropogenic actions [37] and natural physical, chemical, and biological processes. Nevertheless, most methods used for the inventory of geosites or geodiversity sites do not consider data obtained by quantitative assessment of the main geodiversity indicators/criteria. Consequently, some inventoried geosites should have been ascribed to geodiversity sites and vice versa.

In the present research, sixteen sites were analyzed for enhancing geoconservation and promoting geo-education and tourism in the Messina province (Sicily, Southern Italy). The sites showing peculiar geodiversity elements were studied to establish if they were suitable as geosites or geodiversity sites based on indicators used for the geoconservation. Considering that none of the sites identified was inventoried as geosite or geodiversity site, the present research aims to furnish all the information (including the bibliographic background) necessary for the related inventory to protect and adequately manage geodiversity in the Peloritani Mountains, a sector of the Calabria–Peloritani Arc, one important orocline featuring the Geology of the Alpine Mediterranean region. The inventory and quantification of the indicators were also used to identify sites with high potential educational and touristic use. Based on the identified sites, a geo route linking only six of the sixteen studied sites was planned at Alì and Taormina (Messina province). It aims to promote Earth Sciences amongst a wider public and implement geoconservation worldwide.

2. Materials and Methods

A site may be considered provided with high potential educational value when it shows different geological features easily understandable by students, is comfortable, characterized by good safety conditions, and is quick to reach. For educational purposes, the inventory method considers the following parameters: (i) didactic potential (easiness to transfer the geological contents to students), (ii) geological diversity (number of geodiversity elements in the site), (iii) accessibility to the site, and (iv) safety (risk related to the visiting conditions) [37].

A site may be considered provided with high potential tourism value when it shows a significant visual beauty pleasurable for the public, and the site is provided with geological features easily observable and understandable by no experts. For touristic purposes, the inventory method considers the following parameters: (i) scenery (the visual beauty of the site), (ii) interpretative potential (easiness to understand the geological features by tourists), (iii) accessibility to the site, (iv) safety (risk related to the visiting conditions) [37].

Geoconservation uses strategies for identifying, characterizing, and organizing geodiversity provided with some value [8,18]. These geoconservation strategies usually follow a method that considers: (i) inventory, (ii) quantitative assessment, (iii) conservation, (iv) interpretation and promotion, and (v) monitoring of sites [8]. The methods for the inventory and quantification of the indicators used for the geoconservation had to consider the (i) geological background of the territory, (ii) the aims of the inventory, and (iii) the contribution of the scientific geological community [37]. The aims of an inventory had to consider four aspects: topic, value, scale, and use [14]. The method used for the inventory of geosites is aimed at identifying sites with scientific value and is usually based on the following main criteria: (i) representativeness, (ii) integrity, (iii) rarity, and (iv) scientific knowledge. The method used for the inventory of geodiversity sites is usually based on the following four criteria: (i) scenery, (ii) interpretative potential, (iii) accessibility, (iv) safety. The quantitative assessment of the geodiversity is numerically evaluated by considering a weighted sum of the calculated criteria for defining four indicators (scientific value of the geosites, potential educational use, potential touristic use, and degradation risk [37]).

In the present research, criteria, indicators, and methods for geoconservation above reported [37], furtherly completed with parameters established by the regional authority ARTA (Regional Territory and Environment Department) of Sicily [55–57], were applied to the geological heritage of the Peloritani Mountains. The selected geoheritage was checked to verify if inventoried in the Catalogue of the Sicilian Geosites (Regional Law 25/2012) provided by the Regional Department of Territory and Environment ARTA of the Sicilian Region [55]. The inventory was created considering at the same time the above-mentioned adopted criteria and methods as well as the results of the quantification assessment of the indicators used for the geoconservation (Figure 2). The selected sites were analyzed to establish if they were suitable for being ascribed to geosites or geodiversity sites and included in possible activities to improve scientific initiatives, geo-education, and geotourism in this area of southern Italy (Figure 2).

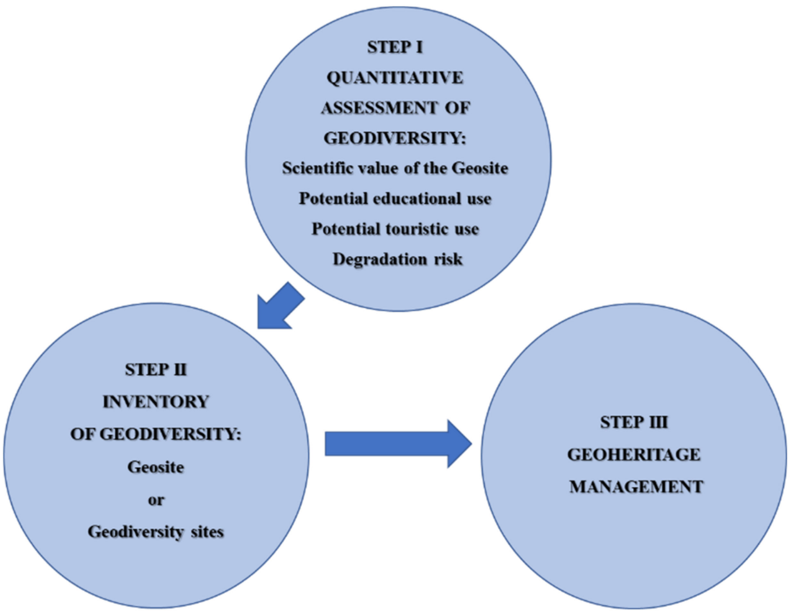

Figure 2. The steps used in the present research for better management of the geoheritage consider the quantitative assessment of geodiversity and the inventory.

3. Results

The sites selected for the protection of the geoheritage and the promotion of education on Earth Sciences are related to sixteen localities of the Alpine chain of the Calabria–

Peloritani Arc (Peloritani Mountains) and involve the rocks of the Alì-Montagnareale and Longi-Taormina Units cropping out in the areas of Alì, Taormina, and Roccella Valdemone (Figure 3). The quantitative assessment of the indicators of the studied geoheritage (Tables 1–4) allowed to define geodiversity elements, ascribing them to geosites or geodiversity sites for a sustainable inventory (Tables 5–20).

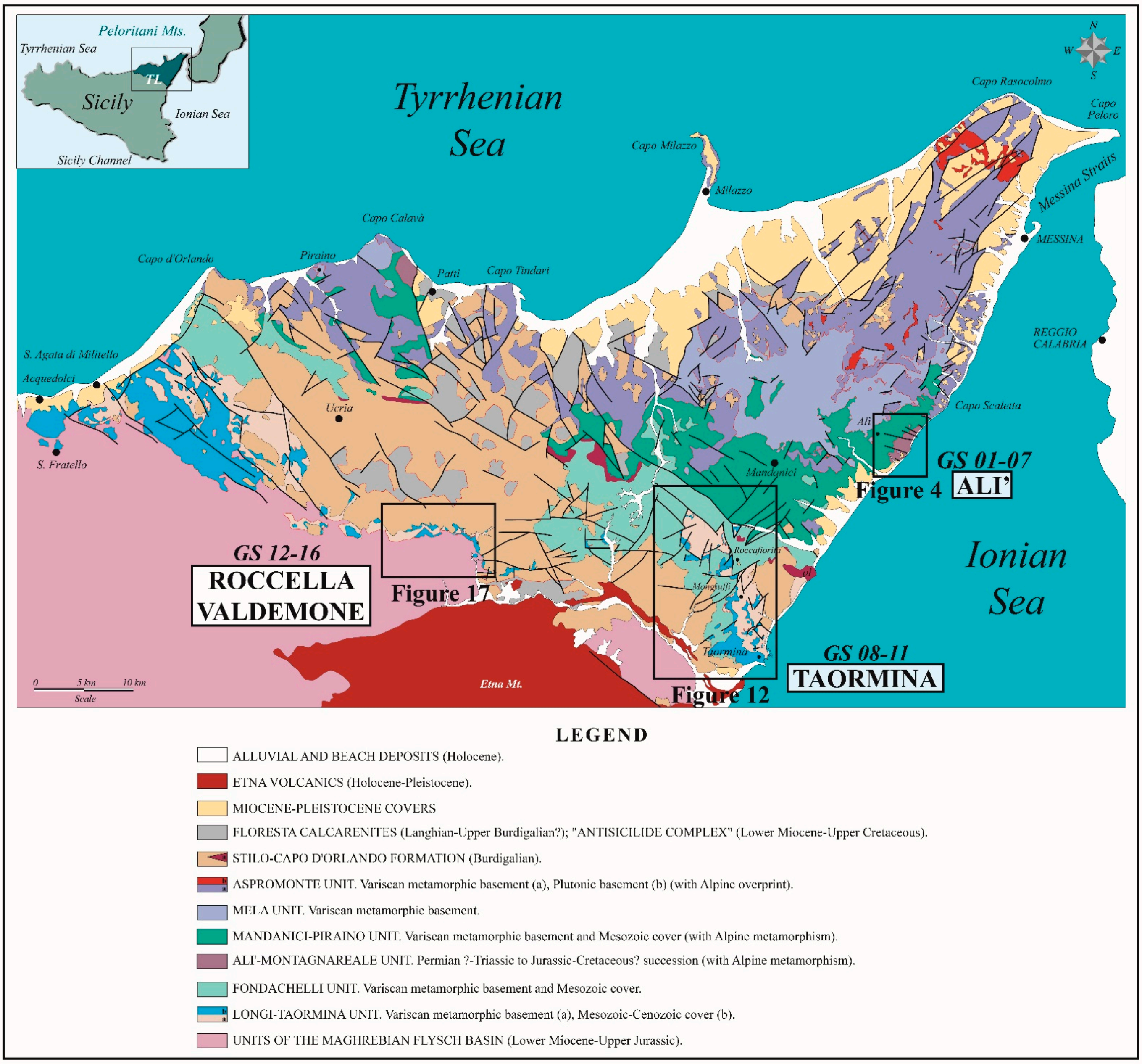

Figure 3. Geological sketch map of the Peloritani Mountains showing the three studied areas (Alì, Taormina, Roccella Valdemone) and the related sixteen sites showing geodiversity elements (GS01-16). In the insert, the geographical position of the Peloritani Mountains is shown with the localization of the Taormina Line (TL).

The names of the geological heritage individuated at Alì, Taormina, and Roccella Valdemone (Figure 3) are:

Alì (GS01-GS07)

1. GS01—Alpine syn-orogenic compression and extension at Capo d'Alì.
2. GS02—Thrust at Rio Schiavo.

3. GS03—Boudin-like structures at Rio Impisi.
4. GS04—Alpine syn-orogenic compression and extension at Rio Impisi.
5. GS05—Modderino klippe.
6. GS06—Thrust of the Mandanici Unit at Puntale Serro.
7. GS07—Marine terrace at Modderino.

Taormina (GS08-GS11)

8. GS08—Thrust at the Monte Veneretta—Monte Pernice ridge.
9. GS09—CS structures at Monte Pernice.
10. GS10—Fold at Monte Galfa.
11. GS11—Thrust of the Fondachelli Unit at Monte Galfa.

Roccella Valdemone (GS12-GS16)

12. GS12—Peloritani Thrust Front in the central sector of the Taormina Line.
13. GS13—Paleozoic pillow lavas at Rocca Licopeti.
14. GS14—Silurian to Devonian conodonts in the Favoscuro west section.
15. GS15—Devonian conodonts in the Favoscuro east section.
16. GS16—Devonian conodonts in the Pizzo Leo section.

3.1. Geological Frameworks

The sixteen sites were individuated on the base of the previous geological, structural, and stratigraphic research accomplished in the last decades by the author together with other Italian and foreign geologists on the Alpine chain of the Calabria–Peloritani Arc [58–76], as well as on the research of others [77–83] and unpublished data of the author. The Calabria–Peloritani Arc originated from the juxtaposition, during the late Miocene, of two different terranes characterized by different tectonic units and evolution. The Alpine chain of the Peloritani Mountains is formed by a thrust pile of Paleozoic to Mesozoic–Cenozoic successions, capped in angular unconformity by post-orogenic Miocene to Quaternary covers (Figure 3; [58–60]). The thrust pile is composed, from top to bottom, by the: Aspromonte, Mela, Mandanici-Piraino, Alì-Montagnareale, Fondachelli, and Longi-Taormina Units (Figure 3; [58–60]). The sixteen sites, studied for their geodiversity contents, are mainly localized in the outcrops of the Alì-Montagnareale Unit [64–69] and Longi-Taormina Units [70–76], and secondarily in the Fondachelli [71], Mandanici, and Aspromonte Units [64–69].

In the study areas, different geological frameworks of significant scientific and geo-educational values were identified:

i. Alpine syn-orogenic compression and extension;
ii. Alpine thrust tectonics;
iii. Miocene block rotations along arc-like structures;
iv. Paleozoic stratigraphy and guide fossils;
v. Pleistocene uplift of the chain and related genesis of marine terraces.

3.1.1. Alpine Syn-Orogenic Compression and Extension

The Peloritani units that were affected by Alpine metamorphism are the Aspromonte, Mandanici-Piraino, and Alì-Montagnareale Units (Figure 3). Alpine metamorphism studied in the Alì-Montagnareale Unit was associated with two main metamorphic events: (i) a first ductile and syn-metamorphic event developed during a contractional deformation phase (D1), (ii) a second one occurred during syn-orogenic extension (D2) [64–66,69]. In the Alì area, there is striking evidence of Alpine tectonic structures indicating syn-orogenic compression and extension. These structures are related to interference patterns of compressional and extensional deformations [64–66,69]. Three main systems of anisotropy surfaces (S0, S1, S2), two main fold systems (F1, F2), and thrust systems are characteristic deformations in the Alì-Montagnareale Unit exposed at Alì. Compressional deformation D1 structures are represented by S-SSW-verging polyharmonic folds F1 showing sub-vertical axial surfaces and axial plane cleavage S1, probably generated during the latest Oligocene

(?)-earliest Aquitanian (?) [64–69]. A cascade fold system F2 testifies to evidence of a synorogenic exhumation, vertical shortening and flattening, and extensional deformation D2e (e = extensional) with sub-horizontal axial surfaces and axial plane cleavage S2 related to the synorogenic horizontal extension. Deformation D2e formed during a second Alpine metamorphic event, which was Early Miocene (?) in age. A third ductile to brittle compressive deformation phase D3 was associated with the development of thrusts that cut previous structures determining striking interference patterns [64–69]. This is particularly evident in the Alì area, where a D3-related and presumably late metamorphic early shear zone was formed during the first stage of nappe stacking of probable Aquitanian to early Burdigalian age [65,69].

3.1.2. Alpine Thrust Tectonics

The shear zone and thrust tectonics involving the Paleozoic to Cenozoic rocks of the Alpine chain of the Peloritani Mountains were characterized by S-SE tectonic transport directions, that occurred during the Aquitanian to early Burdigalian time span. The emplacement of the Peloritani Units on the Maghrebian units occurred in the late Burdigalian [65,69–71]. Thrusts are generally associated with several kinematic indicators and thick phyllonitic and cataclastic belts. Very didactic examples of thrust surfaces may be observed at Alì, Taormina, and Roccella Valdemone.

3.1.3. Miocene Block Rotations along the Arc-like Structures

The Alpine chain is stretched with an E–W trend from the Betic–Rifian Arc to the Himalaya and is characterized in the peri-Mediterranean area by the presence of seven arc-like structures (Betic–Rifian, Calabria–Peloritani, Western Alps, Northern Carpaths, Eastern Carpaths, Dinaro–Hellenid, Tauric Arcs) where rotations generally develop [71]. Significant rotations were recognized along the southern edge of the Calabria–Peloritani Arc in the Peloritani Mountains exposed in the Taormina area. Rotations affected the thrusts determining peculiar "Z-shaped" morphostructural patterns in plan-view due to a transpression zone that occurred during the early Serravallian [70,71]. Very didactic rotated patterns of these thrusts are visible at Taormina.

3.1.4. Paleozoic Stratigraphy and Guide Fossils

The Longi-Taormina Unit preserves the Paleozoic stratigraphy, despite Variscan and Alpine deformation. The reconstructed litho- and biostratigraphic successions are characterized, from base to top, by: (i) Upper Ordovician Castelmola Formation, (ii) Silurian Lower Pizzo Leo Formation, and (iii) Silurian to Devonian Upper Pizzo Leo Formation [75]. The Castelmola and Lower Pizzo Leo Formations are mainly made up of marine siliciclastic deposits and calc-alkaline and alkaline volcanic layers, respectively. The Upper Pizzo Leo Formation comprises pelagic metacarbonates ascribed to the Ludlow up to the Emsian, on the base of fossils, conodonts, and dacryoconarids, in particular [72–76].

The findings of these conodont associations are significant for Paleozoic stratigraphy of this polyorogenic sector of the Alpine chain where, for the first time in the Peloritani Mountains, upper Silurian to lower Devonian beds were dated by means of conodonts [72–76].

3.1.5. Pleistocene Uplift of the Chain and the Related Genesis of Marine Terraces

Sea-level absolute fluctuations and extensional tectonics associated with strong post-orogenic uplift of the Calabria–Peloritani Arc controlled the Quaternary record with heteropic facies distribution within normal fault-controlled graben and horst structures. The terraced marine deposits are widespread along the Messina Straits, stretching along the slopes at different altitudes. The morphological features of the abrasion surfaces and their location concerning recent faults allowed for the reconstruction of the tectogenetic modalities of the post-orogenic uplift [77–80]. Several abrasion surfaces are present along the Ionian side of the Messina Straits. At Alì, it is possible to walk on one of these terraces and observe its features in detail.

3.2. Quantitative Assessment of the Scientific Value of the Geodiversity in the Alì, Taormina, and Roccella Valdemone Areas

The weighted sum of the seven criteria adopted for calculating the scientific value of the geodiversity indicates that eleven sites may be ascribed to geosites (weighted values higher than three) and five to geodiversity sites (weighted values lower than three) (Table 1).

Table 1. Quantitative assessment of the scientific value of the geodiversity (the number between round brackets represents the relative weight).

INDICATORS/ID	GS01	GS02	GS03	GS04	GS05	GS06	GS07	GS08
Representativeness (30)	4	2	4	4	2	2	2	4
Key locality (20)	2	1	2	2	1	1	1	2
Scientific knowledge (5)	4	2	4	4	4	4	4	4
Integrity (15)	4	4	4	4	2	2	4	4
Geological diversity (5)	2	1	2	2	1	1	1	1
Rarity (15)	4	4	4	4	4	4	2	4
Use limitations (5)	4	4	4	4	4	4	4	4
Weighted sum of the scientific value	3.45	2.5	3.4	3.45	2.6	2.6	2.4	3.4
INDICATORS/ID	**GS09**	**GS10**	**GS11**	**GS12**	**GS13**	**GS14**	**GS15**	**GS16**
Representativeness (30)	2	4	4	4	4	4	4	4
Key locality (20)	1	2	2	2	2	2	2	2
Scientific knowledge (5)	4	4	4	4	4	4	4	4
Integrity (15)	2	4	4	4	4	4	4	4
Geological diversity (5)	1	2	1	1	1	2	2	2
Rarity (15)	4	4	4	2	2	4	2	2
Use limitations (5)	4	4	4	4	4	2	4	4
Weighted sum of the scientific value	2.2	3.6	3.4	3	3	3.5	3.2	3.2

3.3. Quantitative Assessment of the Potential Educational Use in the Alì, Taormina, and Roccella Valdemone Areas

The weighted sum of the twelve criteria adopted for calculating the potential educational use indicates that all the sixteen studied sites are characterized by high potential educational use (weighted values higher than three) (Table 2).

Table 2. Quantitative assessment for the potential educational use of the geodiversity (the number between round brackets represents the relative weight).

INDICATORS/ID	GS01	GS02	GS03	GS04	GS05	GS06	GS07	GS08
Vulnerability (10)	1	4	4	1	3	3	3	4
Accessibility (10)	4	4	4	4	4	4	4	4
Use limitations (5)	4	4	4	4	4	4	4	4
Safety (10)	2	2	2	2	2	2	2	2
Logistics (5)	4	4	4	4	4	4	4	4
Density population (5)	3	3	3	3	3	1	1	1
Association with other values (5)	4	4	4	4	4	4	4	4
Scenery (5)	1	1	1	1	1	1	1	1
Uniqueness (5)	4	4	4	4	4	4	2	4
Observation conditions (10)	3	4	4	3	4	4	4	4
Didactic potential (20)	4	4	4	4	4	4	4	4
Geological diversity (10)	4	4	4	4	4	3	3	4

Table 2. *Cont.*

textbfINDICATORS/ID	GS01	GS02	GS03	GS04	GS05	GS06	GS07	GS08
Weighted sum of the educational use	3.2	3.6	3.6	3.2	3.5	3.3	3.2	3.5
INDICATORS/ID	**GS09**	**GS10**	**GS11**	**GS12**	**GS13**	**GS14**	**GS15**	**GS16**
Vulnerability (10)	3	4	3	3	3	4	3	4
Accessibility (10)	4	4	4	3	3	3	3	3
Use limitations (5)	4	4	4	4	4	2	4	4
Safety (10)	2	2	2	2	2	2	2	2
Logistics (5)	4	4	4	4	4	4	4	4
Density population (5)	1	2	2	1	1	1	1	1
Association with other values (5)	3	3	3	4	4	4	4	4
Scenery (5)	1	1	1	1	1	1	1	1
Uniqueness (5)	4	4	4	4	4	4	4	4
Observation conditions (10)	4	4	4	4	4	4	4	4
Didactic potential (20)	4	4	4	4	4	4	4	4
Geological diversity (10)	3	4	3	3	3	3	3	3
Weighted sum of the educational use	3.25	3.5	3.3	3.3	3.2	3.2	3.2	3.3

3.4. Quantitative Assessment of the Potential Touristic Use in the Alì, Taormina, and Roccella Valdemone Areas

The weighted sum of the thirteen criteria adopted for calculating the potential touristic use indicates that only two sites have weighted values higher than three (GS02–GS03) (Table 3).

Table 3. Quantitative assessment of the potential touristic use of the geodiversity (the number between round brackets represents the relative weight).

INDICATORS/ID	**GS01**	**GS02**	**GS03**	**GS04**	**GS05**	**GS06**	**GS07**	**GS08**
Vulnerability (10)	1	4	4	1	3	3	3	4
Accessibility (10)	4	4	4	4	4	4	4	4
Use limitations (5)	4	4	4	4	4	4	4	4
Safety (10)	2	2	2	2	2	2	2	2
Logistics (5)	4	4	4	4	4	4	4	4
Density population (5)	3	3	3	3	3	1	1	1
Association with other values (5)	4	4	4	4	4	4	4	4
Scenery (5)	1	1	1	1	1	1	1	1
Uniqueness (5)	4	4	4	4	4	4	2	4
Observation conditions (10)	3	4	4	3	4	4	4	4
Interpretative potential (10)	1	4	4	1	1	4	4	4
Economic level (5)	1	1	1	1	1	1	1	1
Proximity of recreational areas (5)	4	4	4	4	4	4	4	4
Weighted sum of the touristic use	2.35	3.05	3.05	2.35	2.65	2.85	2.75	2.95
INDICATORS/ID	**GS09**	**GS10**	**GS11**	**GS12**	**GS13**	**GS14**	**GS15**	**GS16**
Vulnerability (10)	3	4	3	3	3	4	3	4

Table 3. *Cont.*

INDICATORS/ID	GS09	GS10	GS11	GS12	GS13	GS14	GS15	GS16
Accessibility (10)	4	4	4	3	3	3	3	3
Use limitations (5)	4	4	4	4	4	2	4	4
Safety (10)	2	2	2	2	2	2	2	2
Logistics (5)	4	4	4	4	4	4	4	4
Density population (5)	1	2	2	1	1	1	1	1
Association with other values (5)	3	3	3	4	4	4	4	4
Scenery (5)	1	1	1	1	1	1	1	1
Uniqueness (5)	4	4	4	4	4	4	4	4
Observation conditions (10)	4	4	4	4	4	4	4	4
Interpretative potential (10)	1	4	4	4	4	1	1	1
Economic level (5)	1	1	1	1	1	1	1	1
Proximity of recreational areas (5)	3	4	3	4	4	4	4	4
Weighted sum of the touristic use	2.45	2.95	2.8	2.75	2.75	2.45	2.45	2.55

3.5. Quantitative Assessment of the Degradation Risk in the Alì, Taormina, and Roccella Valdemone Areas

The weighted sum of the five criteria adopted for calculating the degradation risk indicates that only five sites (GS07–GS11) are provided with low (weighted values lower than two) degradation risks (Table 4). Degradation risk resulted moderate (weighted values between two and three) in six sites (GS06/GS12–GS16) and high (weighted values higher than three) in five sites (GS01–05) (Table 4 and Table 21).

Table 4. Quantitative assessment of the degradation risk of the geodiversity (the number between round brackets represents the relative weight).

INDICATORS/ID	GS01	GS02	GS03	GS04
Deterioration of geological elements (35)	4	2	4	4
Proximity to areas/activities with potential to cause degradation (20)	4	3	4	4
Legal protection (20)	4	4	4	4
Accessibility (15)	3	3	3	3
Density of population (10)	3	3	3	3
Weighted sum of the degradation risk	3.75	3.05	3.75	3.75
INDICATORS/ID	**GS05**	**GS06**	**GS07**	**GS08**
Deterioration of geological elements (35)	2	1	1	1
Proximity to areas/activities with potential to cause degradation (20)	4	4	1	1
Legal protection (20)	4	4	4	4
Accessibility (15)	3	3	1	3
Density of population (10)	3	1	1	1
Weighted sum of the degradation risk	3.05	2.5	1.6	1.9
INDICATORS/ID	**GS09**	**GS10**	**GS11**	**GS12**
Deterioration of geological elements (35)	1	1	1	2

Table 4. *Cont.*

INDICATORS/ID	GS09	GS10	GS11	GS12
Proximity to areas/activities with potential to cause degradation (20)	1	1	1	4
Legal protection (20)	4	4	4	4
Accessibility (15)	2	3	2	3
Density of population (10)	1	2	2	1
Weighted sum of the degradation risk	1.75	2.0	1.85	2.85
INDICATORS/ID	**GS13**	**GS14**	**GS15**	**GS16**
Deterioration of geological elements (35)	2	2	2	1
Proximity to areas/activities with potential to cause degradation (20)	4	4	4	2
Legal protection (20)	4	2	4	4
Accessibility (15)	3	3	3	3
Density of population (10)	1	1	1	1
Weighted sum of the degradation risk	2.85	2.45	2.85	2.1

3.6. Inventory of the Geological Heritage in the Alì Area

The geoheritage inventoried from GS01 to GS07 (Tables 5–11; Figures 4–11) and numerically evaluated (Tables 1–4) is localized in the area of Alì along the Ionian slope of the Messina Straits (Figures 3 and 4). The sites GS01 to GS06 represent a geological framework centered on the topic of Alpine compressive deformation phases and syn-orogenic extension affecting the Alì-Montagnareale Unit and the overlying units (Mandanici and Aspromonte Units) [64–69], whereas the GS07 site is devoted to the Pleistocene uplift of the chain and the related genesis of the marine terraces of the Messina Straits [77–80].

Table 5. Inventory of possible geosite GS01—Alpine syn-orogenic compression and extension at Capo d'Alì.

Name of the geosite	GS01—Alpine syn-orogenic compression and extension at Capo d'Alì
Localization	Alì Terme (Messina, Sicily, Italy)
Geographic Coordinates	38°1′12.77″ N–15°26′25.33″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Structural, Stratigraphic, Paleontological
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The outcrop, localized in the Capo d'Alì, is formed by basin carbonates of the anchimetamorphic succession of the Alì-Montagnareale Unit. The lithostratigraphic succession is represented by Upper Pliensbachian grey cherty metalimestones and metamarly limestones with remnants of belemnites and rare ammonites (mudstones) (Medolo Fm.) 100 m thick. The succession was strongly deformed during two Alpine deformation phases [64–69].	

Table 5. *Cont.*

Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Alpine syn-orogenic compression and extension. The outcrop shows striking and unique Alpine tectonic structures well appreciable on the cliff of Cape Alì. These are related to interference patterns of compressional and extensional deformations. Three systems of anisotropy surfaces (S0, S1, S2) and two fold systems (F1, F2) may be observed. Polyharmonic folds F1 consist of S-SSW-vergent folds with sub-vertical axial surfaces. Folds may show drag folds and cuspate-lobate or open kinks. A steeply dipping syn-metamorphic axial plane cleavage S1 is associated with folds F1. A fold system F2 testifies to syn-orogenic extensional deformation D2e eliminate 2 with sub-horizontal axial surfaces and syn-metamorphic axial plane cleavage S2. D2 exhibits chevrons and kinks [64–69].

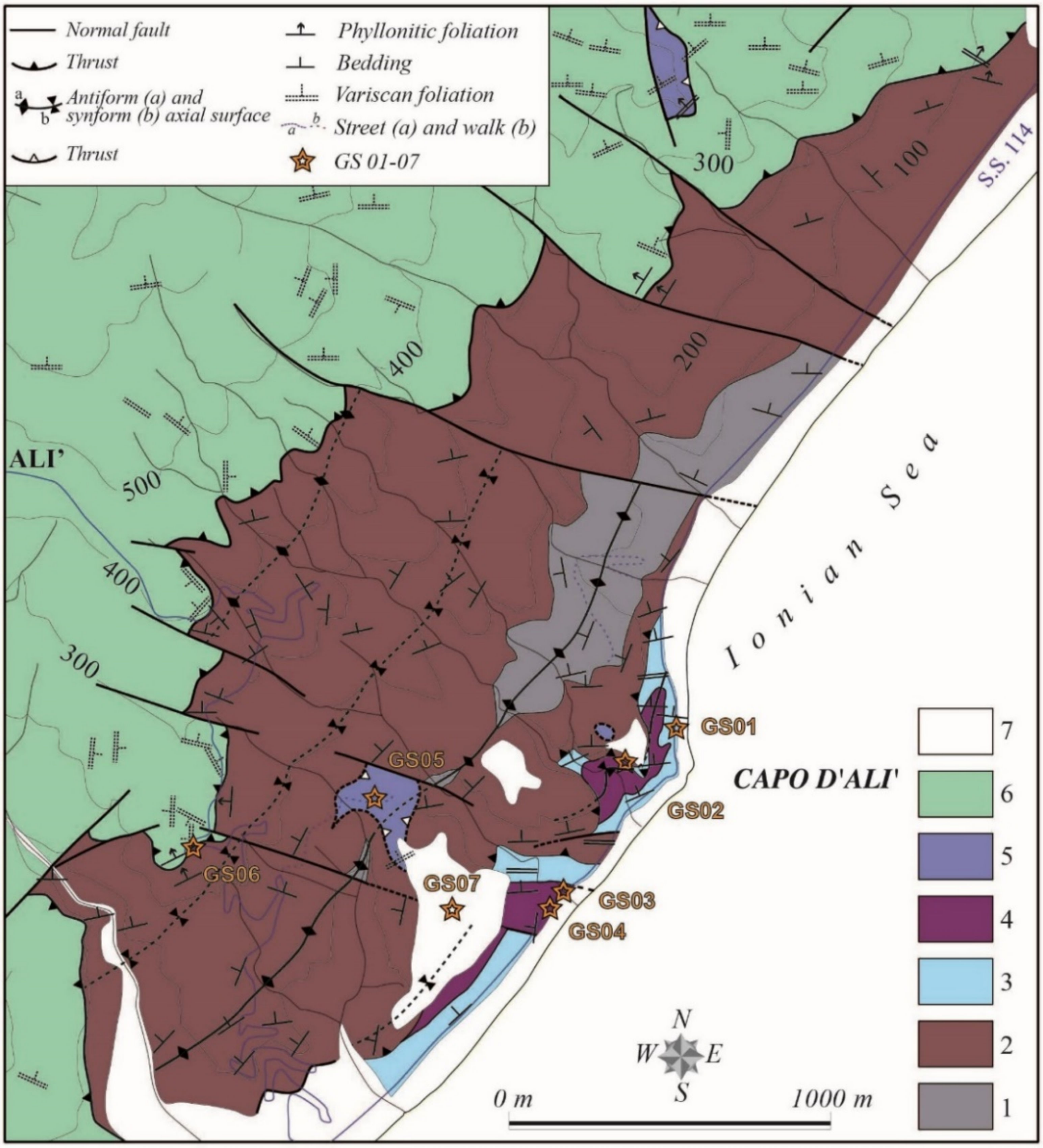

Figure 4. Geological sketch map of the Alì with the inventoried GS01 to GS07 possible geoheritage sites. Legend. Alì-Montagnareale Unit: 1—Scisti neri a piante (Permian-Triassic), 2—Verrucano redbeds, cargneules and gypsum (Middle–Upper Triassic), 3—Medolo-type carbonates (Upper Pliensbachian), 4—Radiolarites, marls, and microbreccias (Jurassic–Cretaceous?). 5—Aspromonte Unit. 6—Mandanici-Piraino Unit. 7—Alluvial and beach deposits, Pleistocene gravels and sandstones, and marine terrace bodies. For localization of the geological map, see Figure 3.

Figure 5. GS01—folds at Capo d'Alì. (**a**) Compressive deformation phase folds F1 (D1). (**b**) Interference pattern between bedding S0, cleavages S1 (D1), and cleavage S2 (D2e) due to syn-orogenic extension.

Table 6. Inventory of the possible geodiversity site GS02—Thrust at Rio Schiavo.

Name of the geodiversity site	GS02—Thrust at Rio Schiavo
Localization	Alì Terme (Messina, Sicily, Italy)
Geographical location of the outcrop	38°1′9.83″ N–15°26′18.59″ E
Geographical location of the observation point (panoramic view)	38°1′4.12″ N–15°26′19.59″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Eventual links with ecological and cultural assets	Non-existent
Eventual use limitations	Non-existent
Safety conditions	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services
Geological description The outcrop is in the Rio Schiavo and shows evidence of thrust tectonics in the Alì-Montagnareale Unit. The hanging wall of the thrust is composed of Triassic cargneules and minor Verrucano beds. Jurassic Medolo limestones to Cretaceous radiolarites and metamarls form the footwall [64–69].	
Geodiversity features with potential educational use: Geological framework–Thrust tectonics. Panoramic view of a thrust with a top-to-SE-wards tectonic transport direction. This thrust is related to compressional deformation phase D3 [64–69].	

Figure 6. GS02—Thrust at Rio Schiavo. The Triassic rocks (hanging wall) overthrust on the Jurassic–Cretaceous rocks (footwall).

Table 7. Inventory of the possible geosite GS03—Boudin-like structures at Rio Impisi.

Name of the geosite	GS03—Boudin-like structures at Rio Impisi
Localization	Alì Terme (Messina, Sicily, Italy)
Geographical location	38°0′56.60″ N–15°26′11.03″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Stratigraphic, Paleontological, Geological-Structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent

Geological description
The Rio Impisi outcrop shows the Alì-Montagnareale Unit's youngest rocks. They are formed by varicolored metamarls alternating with radiolarites and grey cherty metalimestones (locally silicified). Limestones comprise crinoid- or oolite-rich packstone–grainstones and calcareous microbreccias with quartz lithoclasts. Striking slumps affect these rocks. Sedimentary structures and lithofacies suggest turbiditic sedimentation originated from a carbonate platform. Fossil associations with Vidalina (Early Jurassic?), belemnites and Aptychus (Tithonian), calpionellids (Tithonian-Berriasian?), and presumed Globotruncana (late Cretaceous?) are typical fauna of these deposits. Marls are characterized by microfauna assemblage made of Protoglobigerina spp. and abundant pelagic bivalves belonging to the genus Bositra (*B. buchi*?) (late Toarcian to the early Malm in age). Evidence of *Globuligerina oxfordiana* in grainstones intercalated in the metamarls testify to a Callovian–Oxfordian age [64–69].

Most remarkable geological features which justify the need to consider the occurrence as a geosite:
Geological framework—Alpine syn-orogenic compression.The succession is strongly affected by boudin-like structures with pinch and swell structures. Boudin-like structures developed during compressive deformation phase D1 and are associated with the folds F1, being boudin's long axis parallel to folds F1. These structures were coeval with a first Alpine metamorphic event D1 [64–69].

Figure 7. GS03—Boudin-like structures at Rio Impisi. The outcrop shows boudin with pinch and swell structures.

Table 8. Inventory of the possible geosite GS04—Alpine syn-orogenic compression and extension at Rio Impisi.

Name of the geosite	GS04—Alpine syn-orogenic compression and extension at Rio Impisi
Localization	Alì Terme (Messina, Sicily, Italy)
Geographical location	38°0′54.53″ N–15°26′9.48″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Punctual
Geosite state	Under scientific study
Type of main scientific interest	Geological-Structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The site exhibits the same stratigraphy illustrated for the previous GS03.	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Alpine syn-orogenic compression and extension.This site is punctual and covers only a ten of cm^2 wide area of the cliff stretched along the national street. It shows a striking structure where the interference pattern between three deformation phases (D1, D2e, and D3) is observable. The bedding S0 is crosscut with an angle of 45° by a syn-metamorphic foliation S1. The contractional structures D1 are represented by sub-vertical foliation S1, associated with folds F1. A second sub-horizontal syn-metamorphic cleavage S2, locally associated with E–W trending folds F2 characterized by sub-horizontal axial planes, deforms foliation S1. Deformation D2e is due to syn-orogenic extension. Cleavage S2 (S1 and S0) is deformed and crosscut by a thrust with S-wards tectonic transport direction (D3) [64–69].	

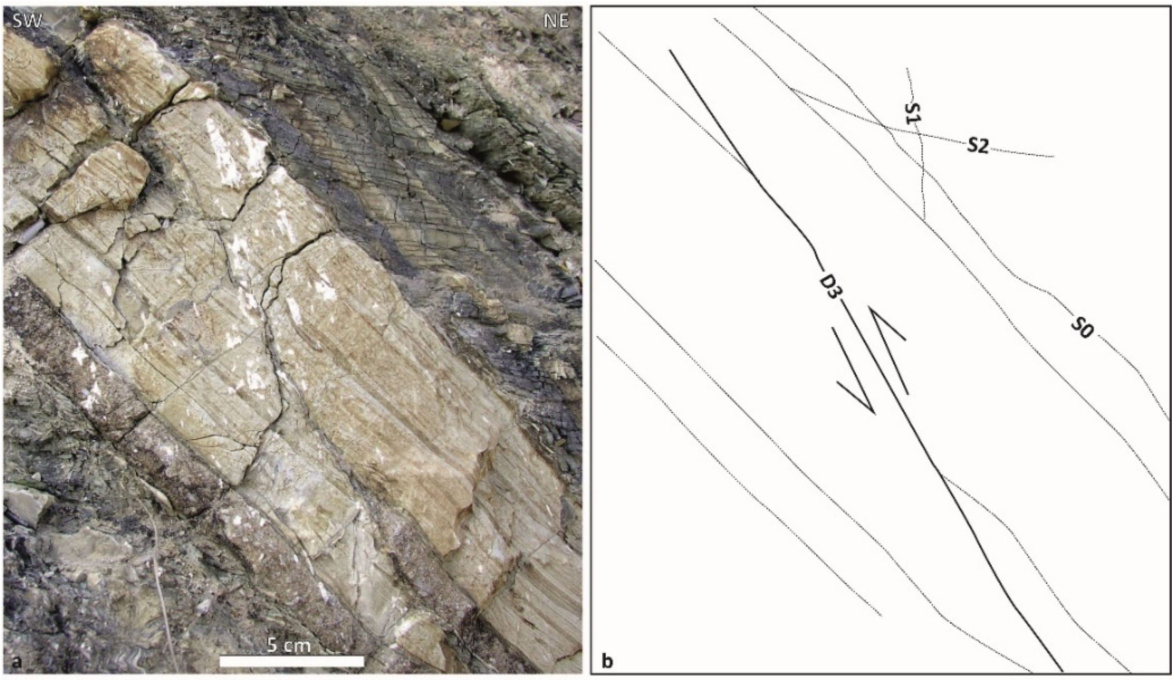

Figure 8. GS04—Alpine syn-orogenic compression and extension at Rio Impisi. The outcrop shows interference pattern between three deformation phases. The syn-orogenic extension is testified by D2, whereas D1 and D3 are compressive phases. The interference pattern is observable on the photograph (**a**) and drawing (**b**).

Table 9. Inventory of the possible geodiversity site GS05—Modderino klippe.

Name of the geodiversity site	GS05—Modderino klippe
Localization	Alì Terme (Messina, Sicily, Italy)
Geographical location	38°1′7.43″ N–15°25′42.71″ E
Owner	Public
Legal protection	Non-existent
Accessibility	Site located less than 100 m from a paved road and with bus park site
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Eventual links with ecological and cultural assets	Non-existent
Eventual use limitations	Non-existent
Safety conditions	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services
Observation conditions	Optimal
Geological description The Modderino klippe is an isolated outcrop of the Aspromonte Unit surrounded by the Alì-Montagnareale Unit. The klippe is formed of Variscan gneiss, whereas the Alì-Montagnareale Unit is made up of Mesozoic Verrucano beds [64–69].	
Geodiversity features with potential educational use: Geological framework—Alpine syn-orogenic compression. The site offers the possibility to observe at the mesoscale a thrust with the chance to analyze the rocks of the hanging wall and the footwall at the same observation point. The thrust appears folded. The thrust tectonics is related to the early stages of the deformation phase D3 [64–69].	

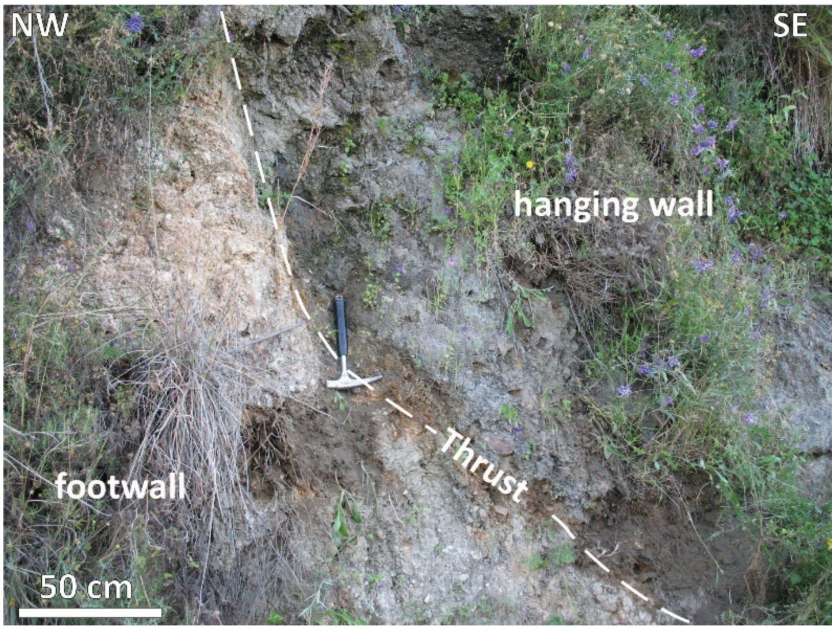

Figure 9. GS05—Modderino klippe. In this outcrop, it is possible to observe a detail of the thrust.

Table 10. Inventory of the possible geodiversity site GS06—Thrust of the Mandanici Unit at Puntale Serro.

Name of the geodiversity site	GS06—Thrust of the Mandanici Unit at Puntale Serro
Localization	Alì (Messina, Sicily, Italy)
Geographical location	38°1′1.84″ N–15°25′26.80″ E
Owner	Public
Legal protection	No-existent
Accessibility	Site located less than 100 m from a paved road and with bus park site
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Eventual links with ecological and cultural assets	Non-existent
Eventual use limitations	Non-existent
Safety conditions	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services
Observation conditions	Optimal
Geological description The site shows the thrust of the Mandanici-Piraino Unit on the Alì-Montagnareale Unit. The hanging wall is made up of Variscan phyllites of the Mandanici-Piraino Unit. The footwall is made up of Mesozoic Verrucano beds of the Alì-Montagnareale Unit [64–69].	
Geodiversity features with potential educational and/or touristic uses: Geological framework—Alpine syn-orogenic compression. This main thrust appears parallel to the minor thrusts affecting the Alì-Montagnareale Unit. The thrust dips NW-wards. A thick shear zone composed of phyllonites with C-S structures indicates a top-to-the-SE tectonic thrusting direction. The Alpine shear zone and thrust tectonics are related to deformation phase D3 [64–69].	

Figure 10. GS06—Thrust of the Mandanici Unit at Puntale Serro. In the outcrop, kinematic indicators (C-S structures) suggest a top-to-the-SE tectonic thrusting direction.

Table 11. Inventory of the possible geodiversity site GS07—Marine terrace at Modderino.

Name of the geodiversity site	GS07—Marine terrace at Modderino
Localization	Modderino, Alì Terme (Messina, Sicily, Italy)
Geographical location of the outcrop	38°0′51.55″ N–15°25′55.29″ E
Geographical location of the observation point (panoramic view)	38°1′22.29″ N–15°25′26.23″ E (Belvedere of Alì)
Owner	Public
Legal protection	Non-existent
Accessibility	Site located less than 100 m from a paved road and with bus park site
Fragility and vulnerability	Potential degrading area
Eventual links with ecological and cultural assets	Non-existent
Eventual use limitations	Non-existent
Safety conditions	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services
Observation conditions	Optimal
Geological description A Pleistocene marine terrace may be observed at Modderino, looking from the panoramic view of Contrada Belvedere [77–80].	
Geodiversity features with potential educational and/or touristic uses: Geological framework—Pleistocene marine terrace. The abrasion marine platform of the Modderino terrace shows an inner margin localized at an elevation of 140 m a.s.l. It was ascribed to the marine isotope substage MIS 5.5 and underwent an uplift characterized by a rate of 1.064 mm/ka [77–80].	

Figure 11. GS07—Marine terrace at Modderino. Aesthetic panoramic view of the abrasion marine platform with the Ionian Sea in the background.

3.7. Inventory of the Geological Heritage in the Taormina Area

The geoheritage inventoried from GS08 to GS11 (Tables 12–15; Figure 3, Figure 12, Figure 13, Figure 14, Figure 15, Figure 16) and numerically evaluated (Tables 1–4) is localized in the area of Taormina along the Ionian slope (Figures 3 and 12). The sites GS08 to GS11 represent a geological framework centered on the topic of Alpine thrust tectonics affecting the Longi-Taormina Unit (Figures 13–15), the overlying Fondachelli Unit (Figure 16), and the underlying units of the Maghrebian Flysh basin, as well as Miocene block rotations along arc-like structures [70–76].

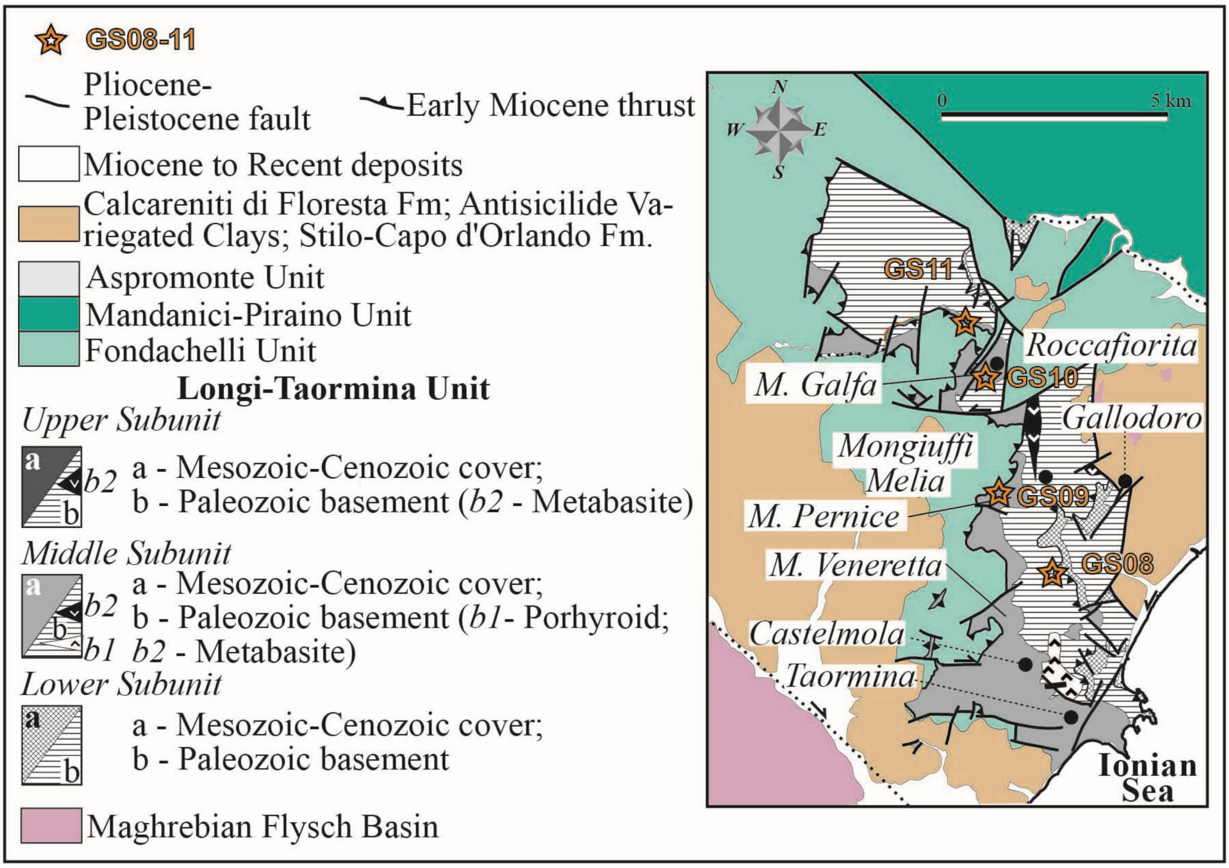

Figure 12. Geological sketch map of the Taormina area with the inventoried GS08 to GS11 possible geoheritage sites. For localization of the geological map, see Figure 3.

Table 12. Inventory of the possible geosite GS08—Thrust at the Monte Veneretta–Monte Pernice ridge.

Name of the geosite	GS08—Thrust at the Monte Veneretta–Monte Pernice ridge
Localization	Gallodoro (Messina, Sicily, Italy)
Geographical location of the outcrop	37°52′27.29″ N–15°16′8.48″ E
Geographical location of the observation point (panoramic view)	37°53′25.97″ N–15°17′7.78″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Structural, Stratigraphic, Paleontological
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent

Geological description
Along the Monte Veneretta–Monte Pernice ridge, it is possible to observe the tectonic thrust stack of the Longi-Taormina Unit. Here it is composed of two minor tectonic units (upper and middle subunits). The Lower Subunit comprises Variscan metamorphic basement and Mesozoic–Cenozoic sedimentary cover (from base to top: continental redbeds, platform carbonates, condensed and basin succession). The Middle Subunit is composed of Variscan metamorphic basement and Mesozoic–Cenozoic sedimentary cover (from base to top: continental redbeds, platform carbonates, basinal marls, limestones, and radiolarites) [70].

Most remarkable geological features which justify the need to consider the occurrence as a geosite:
Geological framework–Alpine thrust tectonics and Miocene block rotations along the arc-like structures.
From this site, it is possible to appreciate a panoramic view of the structural setting of the Longi-Taormina Unit. The Monte Veneretta–Monte Pernice ridge represents a sector of the N–S domain of the "Z-shaped" pattern in plain view. Here, the morphostructural setting of the ridge is characterized by the N–S trend of the thrust sheets of the Longi-Taormina Unit. The structural trends, the strike directions of the thrusts, bedding, fold axes, stretched Jurassic ammonites, and the magnetic lineation (K_{max}) analyzed in the Jurassic medolo limestones are N–S trending. Kinematic indicators (C-S structures) indicate a present-day top-to-the-west shear sense. The thrust of the Monte Veneretta–Monte Pernice ridge consists of an Aquitanian to early Burdigalian frontal ramp that underwent a Serravallian tectonic clockwise rotation. The N–S domain of the "Z-shaped" pattern underwent a W-wards tilting of at least 30–40° [65,69,71].

Figure 13. GS08—Thrust at the Monte Veneretta–Monte Pernice ridge. Aesthetic panoramic view of the frontal ramp and the landscape. The thrust cuts the Paleozoic to Meso-Cenozoic succession of the Longi-Taormina Unit.

Table 13. Inventory of the possible geodiversity site GS09—CS structures at Monte Pernice.

Name of the geodiversity site	GS09—CS structures at Monte Pernice
Localization	Melia (Messina, Sicily, Italy)
Geographical location	37°53′55.06″ N–15°15′49.05″ E
Owner	Public
Legal protection	Non-existent
Accessibility	Site located less than 100 m from a paved road and with bus park site
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Eventual links with ecological and cultural assets	Non-existent
Eventual use limitations	Non-existent
Safety conditions	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services
Observation conditions	Optimal
Geological description The Monte Pernice area represents the northern termination of the N–S domain of the "Z-shaped" pattern in plain view, where the thrusts of the Fondachelli and Longi-Taormina Units are involved [70].	
Geodiversity features with potential educational and/or touristic uses: Geological framework—Alpine thrust tectonics and Miocene block rotations along the arc-like structures. CS-type shear bands may be observed in the *Medolo* limestones. C-planes mainly developed parallel to the bedding S0 whereas S-planes with sigmoidal patterns arranged with angles lower than 45° with respect to C-planes. C- and S-planes are W-wards dipping. Calcite steps present on the C-planes and the C-S patterns indicate a general top-to-the-west shear sense. The C/S fabrics are here interpreted as kinematic indicators of the tectonic transport direction associated with the thrust tectonics affecting this area of the Peloritani Mts. The magnetic lineation (K_{max}) is coherent with other structural data. The N–S trend of the thrust depends on a Serravallian tectonic clockwise rotation. Additionally, in this area, the thrust shows a W-wards tilting of at least 30–40° [70,71].	

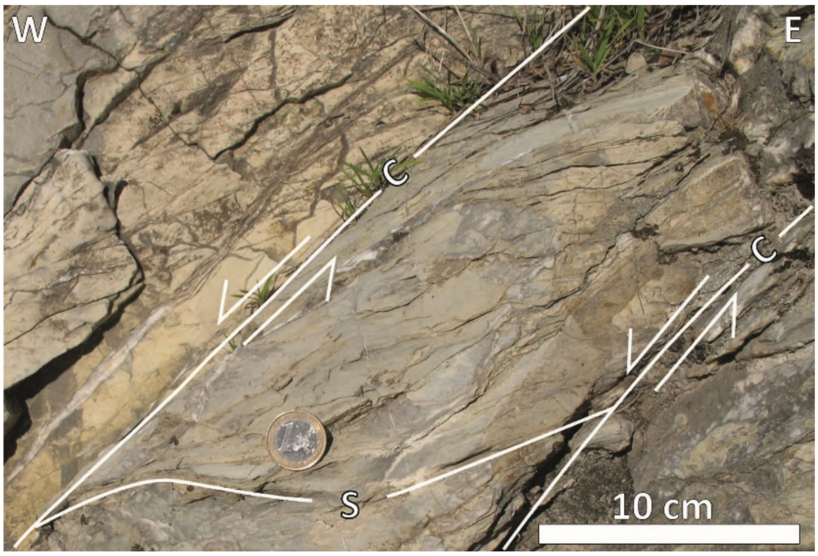

Figure 14. GS09—CS structures at Monte Pernice. The shear zone shows CS structures indicating a top to the West shear.

Table 14. Inventory of the possible geosite GS10—Fold at Monte Galfa.

Name of the geosite	GS10—Fold at Monte Galfa
Localization	Roccafiorita (Messina, Sicily, Italy)
Geographical location of the outcrop	37°55′28.36″ N—15°15′48.41″ E
Geographical location of the observation point (panoramic view)	37°54′47.18″ N—15°16′35.80″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Areal
Geosite state	Under scientific study
Type of main scientific interest	Structural and Stratigraphic
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The Monte Galfa (or Monte Kalfa, 1000 m a.s.l.) area exhibits the Paleozoic to the Mesozoic stratigraphic record of the Longi-Taormina Unit. The Mesozoic cover is here composed, from bottom to top, of redbeds, dolostones, oolitic limestones, and Medolo-type marly limestones [70,71]. The cover is affected by a macroscale fold.	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Alpine thrust tectonics and Miocene block rotations along the arc-like structures. A panoramic view of Monte Galfa allows to observe a fold affecting the Longi-Taormina Unit rocks. The fold at Monte Galfa is localized in the joint area between the northernmost edge of the N–S trending thrusts and the WNW-ESE trending thrusts of the "Z-shaped" morphostructural pattern. The fold presents a W-dipping axial surface with a normal limb dipping W-wards of 30° and a reversed limb dipping NE-wards of 45°. This fold should be associated with thrust tectonics affecting the unit. In present-day coordinates, this fold is an E-verging antiform compatible with the general west-ward anticlockwise tilting of more than 30° observed in the area [70,71].	

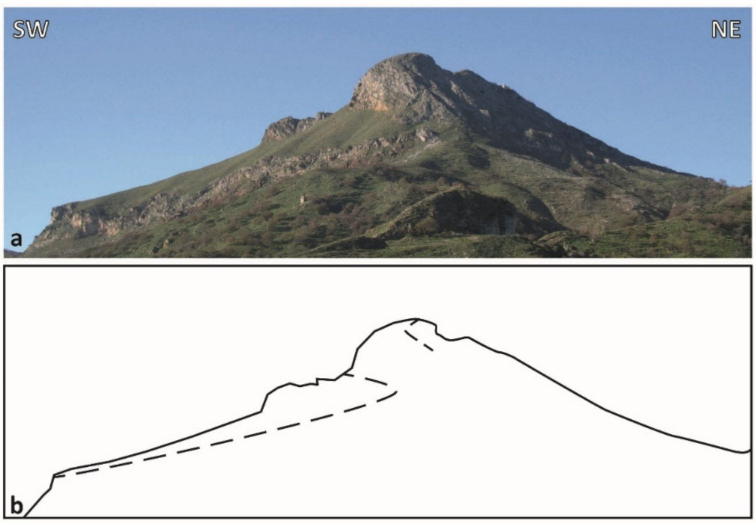

Figure 15. GS10—Fold at Monte Galfa. Aesthetic panoramic view of the fold and landscape. The fold is observable on the photograph (**a**) and drawing (**b**).

Table 15. Inventory of the possible geosite GS11—Thrust of the Fondachelli Unit at Monte Galfa.

Name of the geosite	GS11—Thrust of the Fondachelli Unit at Monte Galfa
Localization	Roccafiorita (Messina, Sicily, Italy)
Geographical location	37°56′1.29″ N–15°15′24.12″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description This site is localized on the north-western slope of Monte Galfa, where it is possible to observe the Aquitanian to early Burdigalian thrust of the Fondachelli Unit on the Longi-Taormina Unit. Variscan phyllites of the Fondachelli Unit form the hanging wall, whereas the footwall is made up of Jurassic dolostones of the Longi-Taormina Unit. The morphostructural transition from the Longi-Taormina Unit to the Fondachelli Unit is visible along the cliff in the dolostones and the moderately dipping slope in the Variscan basement [70,71].	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Alpine thrust tectonics and Miocene block rotations along arc-like structures. The thrust appears WNW–ESE trending and tilted SSW-wards. Kinematic indicators (CS-structures) associated with the thrust of the Fondachelli Unit on the Longi-Taormina Unit show a top-to-the-SSW shear sense. Magnetic lineation (K_{max}) in the Medolo limestones of the Longi-Taormina Unit is WNW-ESE trending. The WNW–ESE structural trend in this area of the “Z-shaped” morphostructural pattern is related to a Serravallian tectonic clockwise rotation [70,71].	

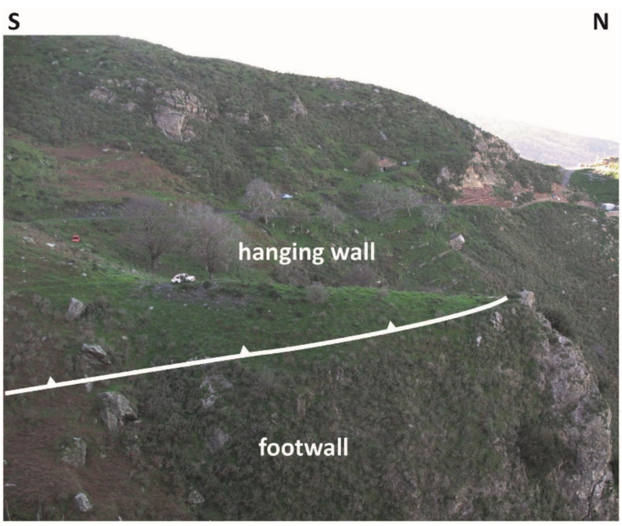

Figure 16. GS11—Thrust of the Fondachelli Unit at Monte Galfa. The Fondachelli Unit (hanging wall) thrusts over the Longi-Taormina Unit (footwall).

3.8. Inventory of the Geological Heritage in the Roccella Valdemone Area

The inventoried geoheritage from GS12 to GS16 (Tables 16–20; Figures 3 and 17–22) and numerically evaluated (Tables 1–4) is localized in the area of Roccella Valdemone along the Taormina Line in the Peloritani–Nebrodi ridge (Figures 3 and 17). The geodiversity present at sites GS12 to GS16 is related to a geological framework centered on the topic of Alpine thrust tectonics, Paleozoic stratigraphy, and guide fossils (conodonts and dacryoconarids) [72–76].

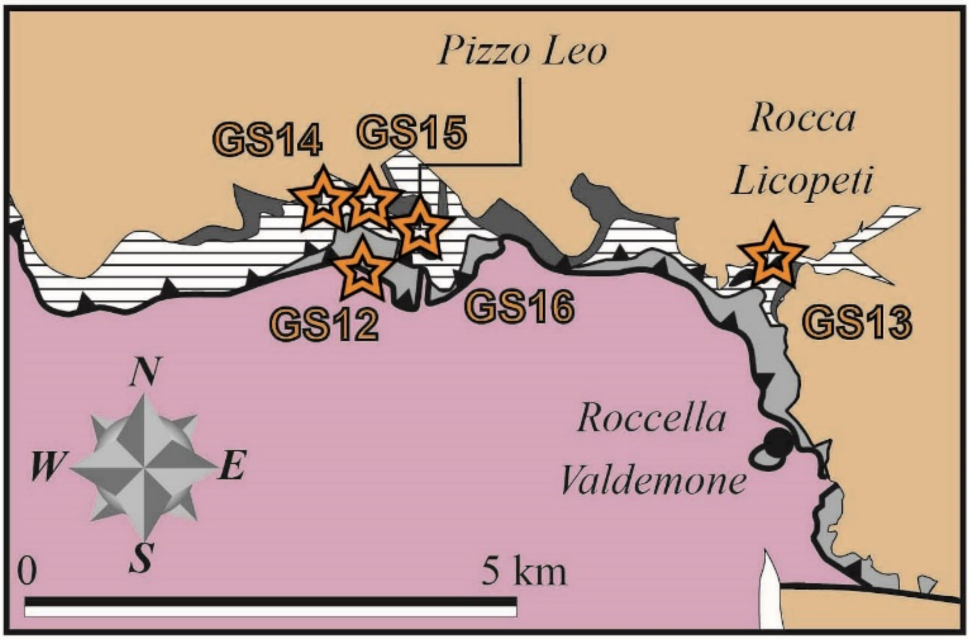

Figure 17. Geological sketch map of the Roccella Valdemone area with the inventoried GS12 to GS16 possible geoheritage sites. For localization of the geological map and the legend, see Figures 3 and 12, respectively.

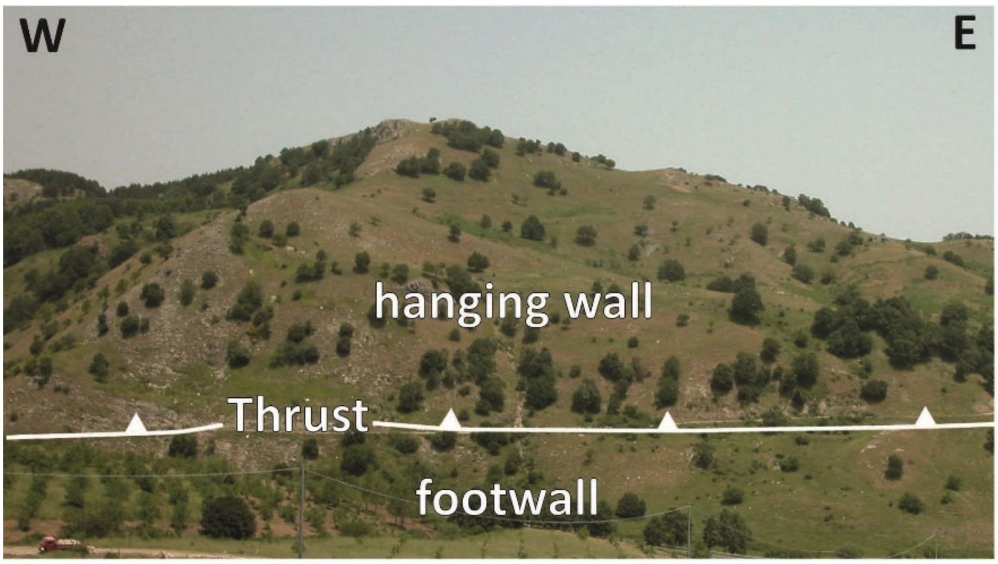

Figure 18. GS12—Peloritani Thrust Front in the central sector of the Taormina Line. In this panoramic view of Pizzo Leo, it is possible to observe the thrust of the Longi-Taormina Unit (hanging wall) on the Units of the Maghrebian Flysch Basin (footwall).

Table 16. Inventory of the possible geosite GS12—Peloritani Thrust Front in the central sector of the Taormina Line.

Name of the geosite	GS12—Peloritani Thrust Front in the central sector of the Taormina Line
Localization	Santa Domenica Vittoria (Messina, Sicily, Italy)
Geographical location	37°57′5.19″ N–14°57′27.15″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Areal
Geosite state	Under scientific study
Type of main scientific interest	Stratigraphic, structural, geomorphological
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The Peloritani Thrust Front (or Taormina Line; Figure 3) represents the Miocene tectonic margin of the Calabria–Peloritani Arc in Sicily. Along this tectonic boundary, the Longi-Taormina Unit of the Alpine Chain overthrusts the more external units of the Maghrebian Flysch Basin [58–62,70,71].	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Alpine thrust tectonics. At the site, it is possible to observe the upper Burdigalian overthrust of the Jurassic limestones of the Longi-Taormina Unit on the lower Cretaceous flysch deposits of the Monte Soro Unit [65,69–71].	

Figure 19. GS13—Paleozoic pillow lavas at Rocca Licopeti. Paleozoic pillow lavas associated with metapelite in the Lower Pizzo Leo Formation at Rocca Licopeti.

Table 17. Inventory of the possible geosite GS13—Paleozoic pillow lavas at Rocca Licopeti.

Name of the geosite	GS13—Paleozoic pillow lavas at Rocca Licopeti
Localization	Roccella Valdemone (Messina, Sicily, Italy)
Geographical location	37°56′53.35″ N–15° 0′32.45″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Volcanic, Petrographic, Mineralogical
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description At Rocca Licopeti, the Paleozoic succession of the Longi-Taormina Unit is composed of metapelites and metarenites, showing layers of metavolcanites with alkaline affinity. These layers belong to the Silurian Lower Pizzo Leo Formation [73,75].	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Paleozoic stratigraphy. These alkaline metavolcanites are composed of dark-green volcanic metabreccias, metatuffs, and metabasalts. The latter show pillow structures with degassing vacuoles, indicating an origin from submarine eruptions [73,75].	

Table 18. Inventory of the possible geosite GS14—Silurian to Devonian conodonts in the Favoscuro west section.

Name of the geosite	GS14—Silurian to Devonian conodonts in the Favoscuro west section
Localization	Floresta (Messina, Sicily, Italy)
Geographical location	37°57′24.92″ N–14°57′13.27″ E
Owner	Public
Legal protection	Existent, being localized in the Nebrodi Park.
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear
Geosite state	Under scientific study
Type of main scientific interest	Stratigraphic, paleontological, structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent

Table 18. *Cont.*

Geological description A stratigraphic section was realized in the Paleozoic succession exposed along the west side of the Favoscuto stream [74]. In the northern part of this section, the lithostratigraphy is characterized, from base to top, by i) a basal lens of nodular metalimestones; ii) metamarls with minor varicolored metapelites and calc-schists with intercalation of calc-schists; iii) calc-schists. In the southern part of the section, the succession is formed by metalimestones with intercalation of metamarls [73–75]. These layers were ascribed to the Silurian Lower Pizzo Leo and the Devonian Upper Pizzo Leo Formations.
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Paleozoic stratigraphy and guide fossils. The calcareous beds sampled in the northern part of the section yielded conodont associations indicating an age ranging from the Ludlow (*Ancoradella ploeckensis–Polygnathoides siluricus* Zones) of the late Silurian to the earliest Emsian (*Polygnathus kitabicus–Polygnathus excavatus* Zones) of the Devonian [74]. The calcareous beds sampled in the southern part of the section yielded conodont associations indicating an age referable to the Emsian (*Polygnathus excavatus* Zone to the *nothoperbonus–inversus* Zones) of the Devonian [73–75].

Figure 20. GS14—Outcrop that has provided Silurian to Devonian conodonts in the Favoscuro west section. Metalimestones of the Silurian Lower Pizzo Leo Formation that yielded Silurian conodonts are visible in the image.

Table 19. Inventory of the possible geosite GS15—Devonian conodonts in the Favoscuro east section.

Name of the geosite	GS15—Devonian conodonts in the Favoscuro east section
Localization	Santa Domenica Vittoria (Messina, Sicily, Italy)
Geographical location	37°57′20.27″ N/14°57′19.22″ E
Owner	Public
Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area/anthropogenic activity
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Linear

Table 19. *Cont.*

Geosite state	Under scientific study
Type of main scientific interest	Stratigraphic, paleontological, structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The Favoscuro East Section consists, from base to top, of a Paleozoic succession made up of: metapelites, strongly deformed metalimestones, platy succession of metapelites and calc-schists, massive iron-rich metalimestone, bedded metalimestones, platy succession of calc-schists and metamarls with platy metalimestone and metapelite intercalations. These layers belong to the Devonian Upper Pizzo Leo Formation [73–75].	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Paleozoic stratigraphy and guide fossils. The taxa found in these Paleozoic beds are represented by mm-sized dacryoconarids and conodont associations, referred to the early Emsian age (*nothoperbonus* Zone) of the Devonian [73–75].	

Figure 21. GS15—Outcrop that has provided Devonian conodonts in the Favoscuro east section. Metalimestones of the Silurian to Devonian Upper Pizzo Leo Formation that yielded conodonts are visible in this image.

Table 20. Inventory of the possible geosite GS16—Devonian conodonts in the Pizzo Leo section.

Name of the geosite	GS16—Devonian conodonts in the Pizzo Leo section
Localization	Santa Domenica Vittoria (Messina, Sicily, Italy)
Geographical location	37°57′13.71″ N–14°57′38.03″ E
Owner	Public

Table 20. *Cont.*

Legal protection	Non-existent
Fragility and vulnerability	Potential degrading area
Accessibility	Site located less than 100 m from a paved road and with bus park site
Geosite category	Areal
Geosite state	Under scientific study
Type of main scientific interest	Stratigraphic, paleontological, structural
Degree of scientific interest	International
Eventual limitations to its scientific use	Non-existent
Geological description The Pizzo Leo stratigraphic succession is made eliminate of, from base to top, of (i) metapelites with lenses of dark green metabasalts and metadolerites of alkaline affinity, with rare intercalations of carbonate lenses and calc-schists in the metapelites overlying the metavolcanites, (ii) metacarbonates, (iii) strongly deformed and recrystallized limestones, evolving upwards to bedded and platy limestones, (iv) metamarls with minor varicolored calc-schists and metapelites [73–75]. These layers belong to the Silurian to Devonian Upper Pizzo Leo Formation.	
Most remarkable geological features which justify the need to consider the occurrence as a geosite: Geological framework—Paleozoic stratigraphy and guide fossils. The platy limestones of the studied Paleozoic succession yielded conodonts assigned to the Lochkovian (delta Zone) of the Devonian [73–75].	

Figure 22. GS16—Devonian conodonts in the Pizzo Leo section. Aesthetic panoramic view of the Pizzo Leo landscape and the Silurian to Devonian Upper Pizzo Leo Formation.

4. Discussion and Conclusions

The Peloritani Mountains (Calabria–Peloritani Arc [58]) have rich geodiversity, showing representative and comprehensive examples of fossils, rocks, and deformations, characterized by a high international scientific value for the future research on Alpine contraction and syn-orogenic extension, on late-orogenic block rotations, and on Paleozoic stratigraphy of the Variscan belt segments reworked within the Alpine Orogen, and by elevated cultural values for geo-education.

Eleven of the sixteen inventoried sites in the eastern sector of the Peloritani Mountains were numerically evaluated as possible geosites (GS01/GS03/GS04/GS08/GS10–16), due to their high scientific value; the other five were inventoried as geodiversity sites (GS02/GS05–07/GS09), due to their lower scientific value (Tables 1 and 21). All the examined sites were provided with a high potential for educational use (Tables 2 and 21). In contrast, only two sites (GS02–GS03) showed a high potential for touristic use, with the others being of moderate use (Tables 3 and 21). Degradation risk is high in five sites (GS01–05), moderate in six sites (GS06/GS12–GS16), and low only in five sites (GS07–GS11) (Tables 4 and 21).

The potential use for geo-education and geotourism may be assessed for geosites to improve their impact on society. Notwithstanding, if the deterioration risk is elevated, no educational and touristic activities may be accomplished [37] as these activities may damage the geodiversity elements. For sustainable use of the geoheritage, only geosites with low degradation risk, or geodiversity sites with low to moderate degradation risk, should be suitable for educational and touristic uses. Based on the above, the following considerations may be made (Tables 1–4 and 21):

i. The sites GS01–GS05, notwithstanding their high potential for educational use, cannot be used for educational purposes due to their elevated degradation risk.
ii. The sites GS02–GS03, notwithstanding their high potential for touristic use, cannot be used for geotourism due to their elevated degradation risk.
iii. The geosites GS12–GS16, notwithstanding their high potential for educational use but considering their moderate degradation risk, cannot be used for education.
iv. The sites GS06 and GS12–GS16, considered to be of moderate potential touristic use, are not significant for geotourism.
v. All the identified geosites should be officially inventoried by the authority ARTA.
vi. The geosites GS01/GS03–GS04/GS12–GS16, considered a high degradation risk, should be subjected to their management with priority.
vii. The management of geosites GS08/GS10–GS11, due to their low degradation risk, should require less urgent intervention to preserve their geodiversity.
viii. The geodiversity sites GS07/GS09 and the geosites GS08/GS10–GS11, being provided with potential educational use and low degradation risk, can be used for educational purposes in their present conditions.
ix. The site GS06, considered its high potential for educational use and the moderate degradation risk, and being a geodiversity site, could be used for educational purposes.

Considering the results of the present quantitative assessment and inventory, an interesting geo-educational initiative could be represented by a geo route linking the geodiversity sites GS06 and GS07 at Alì (Figures 3 and 4) and the sites GS08–GS11 at Taormina (Figures 3 and 12). The main educational topics of this geo route should be devoted to the geological framework of the marine terrace uplift, Alpine thrust tectonics, and Miocene block rotations involving the arc-like structures. The geo route could be planned in two parts: the first could start from Alì, focusing on thrust tectonics and Pleistocene marine terraces; the second could continue the journey from Alì to Taormina, where thrust tectonics and block rotations would be explained. The geo route needs one day and implies a transfer by car/bus of about 30 km from the first site to the last one.

The proposed outcrops are accessible and relatively close to numerous city centers and may allow local visitors to learn about their geoheritage and foreign visitors to learn about peculiar geological processes typical of arc-like structures and Alpine Mountain chains. All stops comprise oral presentations explaining the geodiversity elements and related genesis. The explanation will be calibrated according to the visitors' age and instruction level. Presentations may be carried out using poster presentations and glass panels. Glass panels make it possible to evidence the main geodiversity elements by drawing them on the glass with colored markers posing the board in front of the landscape to describe. For each stop, if the visitors are young students or undergraduates, the visit may be enriched by the planning of games and dynamic activities devoted to simple geological concepts, such as folds and faults. Field trips and gamification are meaningful attractive experiences for students, which may contrast with the increasingly declining interest and low persistence documented among students by recent studies [31]. Notwithstanding considered the difficult degree of the topics, the educational activities should be best addressed to postgraduate geology students in structural geology, tectonics, and stratigraphy, and/or PhD students or young researchers. Activities related to the organization of mass promotion, elaboration of education materials, active exchange with geoparks, and operative collaborations with local and regional institutions are all necessary to improve geoconservation.

Table 21. Synthetic scheme of the quantitative assessment of the geological heritage (the values correspond to the weighted sums reported in Tables 1–4.

ID	Geoheritage	Scientific Value of a Geosite (Score: 1–2–4)	Potential Educational Use (Score: 1–4)	Potential Touristic Use (Score: 1–4)	Degradation Risk (Score: 1–4)
GS01	Geosite	3.45	3.2	2.35	3.75
GS02	Geodiversity site	2.5	3.6	3.05	3.05
GS03	Geosite	3.4	3.6	3.05	3.75
GS04	Geosite	3.45	3.2	2.35	3.75
GS05	Geodiversity site	2.6	3.5	2.65	3.05
GS06	Geodiversity site	2.6	3.3	2.85	2.5
GS07	Geodiversity site	2.4	3.2	2.75	1.6
GS08	Geosite	3.4	3.5	2.95	1.9
GS09	Geodiversity site	2.2	3.25	2.45	1.75
GS10	Geosite	3.6	3.5	2.95	2.0
GS11	Geosite	3.4	3.3	2.8	1.85
GS12	Geosite	3.0	3.3	2.75	2.85
GS13	Geosite	3.0	3.2	2.75	2.85
GS14	Geosite	3.5	3.2	2.45	2.45
GS15	Geosite	3.2	3.2	2.45	2.85
GS16	Geosite	3.2	3.3	2.55	2.1

Analogous educational activities or gamification/game-based learning experiences on Earth Sciences were proposed all over the world, from Ecuador [42] to Iran [43], from China [38] to USA [7,25] or Europe [19,23,26,28,30,32,34,39,45,46,48–53]. During the COVID-10 pandemic, several laboratories could not take place; therefore, natural laboratories for lectures in the fields are necessary and very useful for structural geology and stratigraphic studies. All these key initiatives combining scientific, playful, education, and tourism may represent modern pedagogical approaches using strategic tools for enhancing geoconservation and promoting education for the knowledge of geoheritage among a wider audience. Notwithstanding, for the full development of the proposed geo route, funding and a management policy are necessary.

In conclusion, the quantitative assessment and informal inventory of the geological heritage realized in this sector of southern Italy allowed us to (Tables 1–4 and 21):

i. Identify potential geosites of high international scientific value related to different geological frameworks, urgently subject to official inventory by ARTA and geoconservation.
ii. Exclude several geosites by any possible education and touristic initiatives if no future endeavors are realized in order to lower the degradation risk.
iii. Promote initiatives as geo routes involving sites with proper degradation risk for geoknowledge transfer and geo-education purposes.

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References

1. A Methodology for the Identification of Significant Landforms and Geological Sites for Geoconservation Purposes. Available online: https://eprints.utas.edu.au/11747/ (accessed on 15 May 2022).
2. Dixon, G. *Geoconservation: An International Review and Strategy for Tasmania*; Parks and Wildlife Service: Tasmania, Australia, 1996; pp. 1–101.
3. Wimbleton, W.A.P.; Gerasimenko, N.; Alexandrowicz, Z.; Vinokurov, V.; Liscak, P.; Vozar, A.; Vozarova, A.; Bezak, V.; Kohut, M.; Polak, M.; et al. A first attempt at a geosites framework for Europe—An IUGS initiative to support recognition of world heritage and European geodiversity. *Geol. Balc.* **1998**, *28*, 5–32.
4. Prosser, C.D. Our rich and varied geoconservation portfolio: The foundation for the future. *Proc. Geol. Assoc.* **2013**, *124*, 568–580. [CrossRef]
5. Black, G.P.; Gonggrijp, G.P. Fundamental thoughts on Earth-science conservation. *Jb. Geol. B.-A.* **1990**, *133*, 655–657.
6. Wimbledon, W.A.P. GEOSITES—An International Union of Geological Sciences initiative to conserve our geological heritage. *Pol. Geol. Inst. Spec. Pap.* **1999**, *2*, 5–8.
7. Reuss, R.L.; Gardulski, A.F. An interactive game approach to learning in historical geology and paleontology. *J. Geosci. Educ.* **2001**, *49*, 120–129. [CrossRef]
8. Brilha, J.B. Geoconservation and protected areas. *Environ. Conserv. J.* **2002**, *29*, 273–276. [CrossRef]
9. Santangelo, N.; Santo, A.; Guida, D.; Lanzara, R.; Siervo, V. The geosites of the Cilento-Vallo di Diano national park (Campania region, southern Italy). *Il Quat. Ital. J. Quat. Sci.* **2005**, *18*, 103–114.
10. Erikstad, L. History of geoconservation in Europe. In *The History of Geoconservation*; Burek, C.V., Prosser, C.D., Eds.; Geological Society, Special Publications: London, UK, 2008; pp. 249–256.
11. Gray, J.M. Geodiversity: Developing the paradigma. *Proc. Geol. Assoc.* **2008**, *119*, 287–298. [CrossRef]
12. Gray, J.M. *Geodiversity: Valuing and Conserving Abiotic Nature*, 2nd ed.; Wiley-Blackwell: Chichester, UK, 2013; p. 512. ISBN 978-0-470-74215-0.
13. Joyce, E.B. Australia's Geoheritage: History of Study, A New Inventory of Geosites and Applications to Geotourism and Geoparks. *Geoheritage* **2010**, *2*, 39–56. [CrossRef]
14. Lima, F.F.; Brilha, J.B.; Salamuni, E. Inventorying geological heritage in large territories: A methodological proposal applied to Brazil. *Geoheritage* **2010**, *2*, 91–99. [CrossRef]
15. McKeever, P.; Zouros, N.; Patzak, M.; Weber, J. The UNESCO global network of national geoparks. In *Geotourism: The Tourism of Geology and Landscape*; Newsome, D., Dowling, R., Eds.; Goodfellow Publishers Ltd.: Oxford, UK, 2010; pp. 221–230.
16. Prosser, C.D.; Burek, C.V.; Evans, D.H.; Gordon, J.E.; Kirkbride, V.B.; Rennie, A.F.; Walmsley, C.A. Conserving geodiversity sites in a changing climate: Management challenges and responses. *Geoheritage* **2010**, *2*, 123–136. [CrossRef]
17. Ruban, D.A. Quantification of geodiversity and its loss. *Proc. Geol. Assoc.* **2010**, *121*, 326–333. [CrossRef]
18. Henriques, M.H.; Pena dos Reis, R.; Brilha, J.; Mota, T.S. Geoconservation as an emerging geoscience. *Geoheritage* **2011**, *3*, 117–128. [CrossRef]
19. Fermeli, G.; Meléndez, G.; Calonge, A.; Dermitzakis, M.; Steininger, F.; Koutsouveli, A.; Neto de Carvalho, C.; Rodrigues, J.; D'Arpa, C.; Di Patti, C. Geoschools: Innovative teaching of geosciences in secondary schools and raising awareness on geoheritage in the society. In *Avances y Retos en la conservación del Patrimonio Geológico en España*; Fernández-Martínez, E., Castaño de Luis, R., Eds.; Actas de la IX Reunión Nacional de la Comisión de Patrimonio Geológico (SGE): León, Spain, 2011; pp. 120–124.
20. Browne, M.A.E. Geodiversity and the role of the planning system in Scotland. *Scott. Geogr. J.* **2012**, *128*, 266–277. [CrossRef]
21. Fassoulas, C.; Mouriki, D.; Dimitriou-Nikolakis, P.; Iliopoulos, G. Quantitative assessment of geotopes as an effective tool for geoheritage management. *Geoheritage* **2012**, *4*, 177–193. [CrossRef]
22. Bollati, I.; Smiraglia, C.; Pelfini, M. Assessment and selection of geomorphosites and trails in the Miage Glacier Area (Western Italian Alps). *Environ. Manag.* **2013**, *51*, 951–967. [CrossRef]
23. Magagna, A.; Ferrero, E.; Giardino, M.; Lozar, F.; Perotti, L. A selection of geological tours for promoting the Italian geological heritage in the secondary schools. *Geoheritage* **2013**, *5*, 265–273. [CrossRef]

24. Pereira, D.I.; Pereira, P.; Brilha, J.; Santos, L. Geodiversity assessment of Paraná State (Brazil): An innovative approach. *Environ. Manag.* **2013**, *52*, 541–552. [CrossRef]
25. Clary, R.M.; Wandersee, J.H. Lessons from US fossil parks for effective informal science education. *Geoheritage* **2014**, *6*, 241–256. [CrossRef]
26. Fuertes-Gutiérrez, I.; Pérez Arlucea, M.; González-Villanueva, R.; Arias Ferrero, F.; Hernández-Paredes, R.; De Miguel Ximénez, C.J.; Escorihuela, J.; Cuevas-González, J.; García-Aguilar, J.M. El valor didáctico del patrimonio geológico y el valor patrimonial de los recursos didácticos. *Ensen. Cienc.* **2014**, *22*, 69–80.
27. Reis, J.; Póvoas, L.; Barriga, F.J.A.S.; Lopes, C.; Santos, V.F.; Ribeiro, B.; Cascalho, J.; Pinto, A. Science education in a museum: Enhancing earth sciences literacy as a way to enhance public awareness of geological heritage. *Geoheritage* **2014**, *6*, 217–223. [CrossRef]
28. Rodríguez-Pérez, E.; Romero-Nieto, D.; Fesharaki, O. Gymkhana geourbana como método didáctico y de motivación de estudiantes de geologia. *Reduca* **2014**, *6*, 1–25.
29. Santangelo, N.; Romano, P.; Santo, A. Geo-itineraries in the Cilento Vallo di Diano Geopark: A Tool for Tourism Development in Southern Italy. *Geoheritage* **2014**, *7*, 319–335. [CrossRef]
30. Vidal-Meló, A.V.; Sala, B.R.; Fuster, V.D.E.; Planes, F.J.B. A gymkhana to discover and generate curves in a cooperative work. *Multidiscip. J. Educ. Soc. Technol. Sci.* **2014**, *1*, 53–68. [CrossRef]
31. Bursztyn, N.; Pederson, J.; Shelton, B.; Walker, A.; Campbell, T. Utilizing geo-referenced mobile game technology for universally accessible virtual geology field trips. *Int. J. Educ. Math. Sci. Technol.* **2015**, *3*, 93–100. [CrossRef]
32. Fermeli, G.; Meléndez, G.; Koutsouveli, A.; Dermitzakis, M.; Calonge, A.; Steininger, F.; D'Arpa, C.; Di Patti, C. Geoscience teaching and student interest in secondary schools-preliminary results from an interest research in Greece, Spain and Italy. *Geoheritage* **2015**, *7*, 13–24. [CrossRef]
33. Lagally, U.; Loth, R.; Schindelmann, C. The "day of Geosites" in Germany—A successful promotion tool for earth sciences. *Geoheritage* **2015**, *7*, 195–204. [CrossRef]
34. Sanchez, E.; Kalmpourtzis, G.; Cazes, J.; Berthoix, M.; Monod-Ansaldi, R. Learning with Tactileo Map: From Gamification to Ludicization of Fieldwork. *GI Forum J. Geo. Minds Soc.* **2015**, *1*, 261–271. [CrossRef]
35. Wang, L.; Tian, M.; Wang, L. Geodiversity, geoconservation and geotourism in Hong Kong Global Geopark of China. *Proc. Geol. Assoc.* **2015**, *126*, 426–437. [CrossRef]
36. Al-Azawi, R.; Al-Faliti, F.; Al-Blushi, M. Educational Gamification vs game based learning: Comparative study. *Int. J. Innov. Manag. Technol.* **2016**, *7*, 132–136. [CrossRef]
37. Brilha, J.B. Inventory and Quantitative Assessment of Geosites and Geodiversity Sites: A Review. *Geoheritage* **2016**, *8*, 119–134. [CrossRef]
38. Chen, C.L.D.; Yeh, T.K.; Chang, C.Y. The effects of game-based learning and anticipation of a test on the learning outcomes of 10th grade geology students. *Eurasia J. Math. Sci. Technol. Educ.* **2016**, *12*, 1379–1388. [CrossRef]
39. Crespo-Blanc, A.; Alfaro, P.; Alonso-Zarza, A.; Aurell, M.; Calonge, A.; Carcavilla, L.; Corral, I. Geolodía para un público numeroso: Claves para su organización. *Geogaceta* **2016**, *59*, 91–94.
40. Santangelo, N.; Bravi, S.; Santo, A. Itinerario 12 Piana del Sele, Monti Alburni e Vallo di Diano. In *Guide Geologiche Regionali-Campania e Molise*; Calcaterra, D., D'Argenio, B., Ferranti, L., Pappone, G., Petrosino, P., Eds.; Società Geologica Italiana: Rome, Italy, 2016; pp. 227–242.
41. Karagiorgas, D.N.; Niemann, S. Gamification and game-based learning. *J. Educ. Technol. Syst.* **2017**, *45*, 499–519. [CrossRef]
42. Kelley, D.; Salazar, R. Geosites in the Galápagos Islands used for geology education programs. *Geoheritage* **2017**, *9*, 351–358. [CrossRef]
43. Torabi Farsani, N.; Mortazavi, M.; Bahrami, A.; Kalantary, R.; Khosravi Bizhaem, F. Traditional crafts: A tool for geo-education in geotourism. *Geoheritage* **2017**, *9*, 577–584. [CrossRef]
44. Barasoain, D.; Azanza, B. Geoheritage and education: A practical example from the Rhinoceros of Toril 3 (Calatayud-Daroca Basin, Spain). *Geoheritage* **2018**, *10*, 363–374. [CrossRef]
45. Berrocal-Casero, M.; Arribas, M.; Moratalla, J.J. Didactic and divulgative resources of the middle Triassic vertebrate tracksite of Los Arroturos (province of Guadalajara, Spain). *Geoheritage* **2018**, *10*, 375–384. [CrossRef]
46. Martín Abad, H.; Blanco Moreno, C.; Barrios de Pedro, S.; Marugán-Lobón, J.; Poyato Ariza, F.J.; Delvene, G.; Moratalla, J.J.; Fregenal Martínez, M.; Vullo, R.; Cuesta, E.; et al. The exceptional fossil site of Las Hoyas (Spain) from an educational perspective. *Geoheritage* **2018**, *10*, 463–472. [CrossRef]
47. Giannetti, A.; Monaco, P.; Falces-Delgado, S.; La Iacona, F.G.; Corbí, H. Taphonomy, ichnology, and palaeoecology to distinguish event beds in varied shallow-water settings (Betic cordillera, SE Spain). *J. Iber. Geol.* **2019**, *45*, 47–61. [CrossRef]
48. Punturo, R.; Ortolano, G.; Visalli, R.; Caffo, S.; Ferlito, C.; Cirrincione, R. Geoscience and education: Proposal of a Geo-trail at the Etna volcano. *Rend. Online Soc. Geol. Ital.* **2019**, *49*, 55–61. [CrossRef]
49. Cuevas-González, J.; Díez-Canseco, D.; Alfaro, P.; Andreu, J.M.; Baeza-Carratalá, J.F.; Benavente, D.; Blanco-Quintero, I.F.; Cañaveras, J.C.; Corbí, H.; Delgado, J.; et al. Geogymkhana-Alicante (Spain): Geoheritage Through Education. *Geoheritage* **2020**, *12*, 1–11. [CrossRef]
50. Santangelo, N.; Amato, V.; Ascione, A.; Russo Ermolli, E.; Valente, E. Geotourism as a Tool for Learning: A Geoitinerary in the Cilento, Vallo di Diano and Alburni Geopark (Southern Italy). *Resources* **2020**, *9*, 67. [CrossRef]

51. Spoto, S.E.; Somma, R.; Crea, F. Using a forensic-based learning approach to teach geochemistry. *AAPP Atti Accad. Peloritana Pericolanti Cl. Sci. Fis. Mat. Nat.* **2021**, *99*, A31. [CrossRef]
52. Pardo-Igúzquiza, E.J.; Durán-Valsero, J.A.; Dowd, P.; Luque-Espinar, J.A.; Heredia, J.; Robledo-Ardila, P.A. Geodiversity of closed depressions in a high relief karst: Geoeducation asset and geotourism resource in the "Sierra de las Nieves" National Park (Málaga Province, Southern Spain). *Int. J. Geoheritage Parks* **2022**, *10*, 196–217. [CrossRef]
53. Somma, R. Advances in Flipped Classrooms for Teaching and Learning Forensic Geology. *Educ. Sci.* **2022**, *12*, 403. [CrossRef]
54. UNESCO Global Geoparks Operational Guidelines. Available online: www.unesco.org (accessed on 29 April 2022).
55. Catalogo Regionale dei Geositi. Available online: https://dati.regione.sicilia.it/dataset/catalogo-regionale-dei-geositi (accessed on 8 July 2022).
56. Gole Della Tardara (AG). Available online: https://www.geositidisicilia.it/03_gole-tardara.html (accessed on 8 July 2022).
57. Geositi Istituiti Aree. Available online: https://www.sitr.regione.sicilia.it/geoportale/it/metadata/details/748 (accessed on 8 July 2022).
58. Bonardi, G.; Caggianelli, A.; Critelli, S.; Messina, A.; Perrone, V.; Acquafredda, P.; Carbone, G.; Careri, G.; Cirrincione, R.; D'errico, M.; et al. Geotraverse across the Calabria-Peloritani Terrane (Southern Italy). In *Memorie Descrittive Della Carta Geologica d'Italia. Field Trip Guide Book—P66, Proceedings of the 32nd International Geological Congress IUGS, Florence, Italy, 20–28 August 2004*; Geologico d'Italia—APAT: Rome, Italy, 2004; pp. 1–60.
59. Messina, A.; Somma, R.; Macaione, E.; Carbone, G.; Careri, G. Peloritani continental crust composition (southern Italy): Geological and petrochemical evidence. *Boll. Soc. Geol. Ital.* **2004**, *123*, 405–441.
60. Iannace, A.; Vitale, S.; D'errico, M.; Mazzoli, S.; Di Staso, A.; Macaione, E.; Messina, A.; Reddy, S.M.; Somma, R.; Zamparelli, V.; et al. The carbonate tectonic units of northern Calabria (Italy): A record of Apulian paleomargin evolution and Miocene convergence, continental crust subduction, and exhumation of HP-LT rocks. *J. Geol. Soc.* **2007**, *164*, 1165–1186. [CrossRef]
61. Di Paolo, L.; Aldega, L.; Corrado, S.; Somma, R.; Balestrieri, M.L.; Maniscalco, R. Paleo-thermal and structural indicators for unraveling burial/exhumation paths in the Peloritani Mts. (NE Sicily, Italy). In Proceedings of the 72nd European Association of Geoscientists and Engineers Conference and Exhibition 2010: A New Spring for Geoscience. Incorporating SPE EUROPEC 2010, Barcelona, Spain, 14–17 June 2010.
62. Aldega, L.; Corrado, S.; Di Paolo, L.; Somma, R.; Maniscalco, R.; Balestrieri, M.L. Shallow burial and exhumation of the Peloritani Mountains (NE Sicily, Italy): Insight from paleothermal and structural indicators. *Geol. Soc. Am. Bull.* **2011**, *123*, 132–149. [CrossRef]
63. De Capoa, P.; D'errico, M.; Di Staso, A.; Perrone, V.; Somma, R.; Zaghloul, M.N. Biostratigraphic constraints for the palaeogeographic and tectonic evolution of the Alpine Central-Western Mediterranean orogenic belt (Betic, Maghrebian and Apenninic chains). *Rend. Online Soc. Geol. Ital.* **2013**, *25*, 43–63. [CrossRef]
64. Somma, R.; Messina, A.; Mazzoli, S. Syn-orogenic extension in the Peloritani Alpine Thrust Belt (NE Sicily, Italy): Evidence from the Alì unit. *C. R.-Geosci.* **2005**, *337*, 861–871. [CrossRef]
65. Somma, R.; Martin-Rojas, I. From Alpine syn-orogenic deformation to late-orogenic clockwise rotations in the Calabria-Peloritani Arc: A geological journey from Alì to Taormina-Mongiuffi-Roccafiorita (Sicily, Southern Italy). In *Geological Field Book, Proceedings of the XXIII Reunión de la Comisión de Tectónica, Messina, Italy, 23–26 June 2011*; Sociedad Geológica de España: Salamanca, Spain, 2011; Available online: https://sge.usal.es/comisiones/memorias_tectonica/memoria_23.pdf (accessed on 5 June 2022).
66. Somma, R.; Martin-Rojas, I. A preliminary tectonic model for interpreting the Peloritani Alpine metamorphism. In Proceedings of the Riunione Annuale Gruppo Informale di Geologia Strutturale GIGS 2013, Milano, Italy, 28–30 October 2013.
67. Somma, R.; Martin Rojas, I.; Perrone, V. The stratigraphic record of the Alì-Montagnareale Unit (Peloritani Mountains, NE Sicily). *Rend. Online Soc. Geol. Ital.* **2013**, *25*, 106–115. [CrossRef]
68. Somma, R.; Cascio, M.; Silvestro, M.; Torre, E. A GIS-based quantitative approach for the search of clandestine graves, Italy. *J. Forensic Sci.* **2018**, *63*, 882–898. [CrossRef] [PubMed]
69. Somma, R. From Alpine syn-orogenic deformation to late-orogenic clockwise rotations in the Calabria-Peloritani Arc (NE Sicily, southern Italy). In *Geo-Guías, Rutas Geológicas por la Península Ibérica, Canarias, Sicilia y Marruecos, XXX Aniversario de la Comisión de Tectónica de la SGE.*; Diaz Azpiroz, M., Exposito Ramos, I., Funez, S.L., Baulus Lazaro, B., Eds.; Sociedad Geologica de Espana: Madrid, Spain, 2019; Volume 11, pp. 265–274. ISSN 2254-6138.
70. Somma, R.; Messina, A.; Perrone, V. The Cambrian to Aquitanian geological record of the Longi-Taormina Unit (Calabria-Peloritani Arc, southern Italy): Geodynamic implications. *Geodin. Acta* **2005**, *18*, 417–430. [CrossRef]
71. Somma, R. The south-western side of the Calabrian Arc (Peloritani Mountains): Geological, structural and AMS evidence for passive clockwise rotations. *J. Geodyn.* **2006**, *41*, 422–439. [CrossRef]
72. Navas-Parejo, P.; Somma, R.; Martín-Algarra, A.; Perrone, V.; Rodríguez-Cañero, R. First record of Devonian orthoceratid-bearing limestones in southern Calabria (Italy). *Comptes Rendus—Palevol.* **2009**, *8*, 365–373. [CrossRef]
73. Somma, R.; Navas-Parejo, P.; Martín-Algarra, A.; Martínez-Pérez, C.; Perrone, V.; Rodríguez-Cañero, R. Vincoli biostratigrafici sull'età del vulcanismo alcalino paleozoico dei Monti Peloritani (Sicilia nord-orientale) [Biostratigraphic constraints on the Palaeozoic alkaline volcanism of the Peloritani Mountains (north-eastern Sicily)]. In Proceedings of the 86° Congresso Nazionale Società Geologica Italiana (SGI), Arcavacata di Rende, Cosenza, Italy, 18–20 September 2012.

74. Rodriguez-Canero, R.; Navas-Parejo, P.; Somma, R.; Martin-Algarra, A.; Perrone, V. First finding of upper Silurian and Lower Devonian conodonts from the Peloritani Mountains (NE Sicily, southern Italy). *Boll. Soc. Paleontol. Ital.* **2013**, *52*, 113–121. [CrossRef]
75. Somma, R.; Navas-Parejo, P.; Martín-Algarra, A.; Rodríguez-Cañero, R.; Perrone, V.; Martínez-Pérez, C. Paleozoic stratigraphy of the Longi-Taormina Unit (Peloritanian Mountains, southern Italy). *Stratigraphy* **2013**, *10*, 127–152.
76. Navas-Parejo, P.; Somma, R.; Rodríguez-Cañero, R.; Martín-Algarra, A.; Perrone, V. Conodont-based stratigraphy in the Devonian of the Serre Massif (southern Italy). *Stratigraphy* **2015**, *12*, 1–21.
77. Bonfiglio, L. Correlazioni tra depositi a mammiferi, depositi marini, linee di costa e terrazzi medio e tardo-pleistocenici nella Sicilia orientale. *Il Quat.* **1991**, *4*, 205–214.
78. Catalano, S.; Cinque, A. L'evoluzione neotettonica dei Peloritani settentrionali (Sicilia nord-orientale): Il contributo di una analisi geomorfologica preliminare. *Studi Geol. Camerti* **1995**, *2*, 113–123.
79. Lentini, F.; Catalano, S.; Carbone, S. *Note Illustrative Della Carta Geologica Della Provincia di Messina. Scala 1: 50.000*; SELCA: Florence, Italy, 2000; pp. 1–70.
80. Catalano, S.; De Guidi, G.; Monaco, C.; Tortorici, G.; Tortorici, L. Long-term behaviour of the late quaternary normal faults in the Straits of Messina area (Calabrian arc): Structural and morphological constraints. *Quat. Intern.* **2003**, *101*, 81–91. [CrossRef]
81. Appel, P.; Cirrincione, R.; Fiannacca, P.; Pezzino, A. Age constraints on Late Paleozoic evolution of continental crust from electron microprobe dating of monazite in the Peloritani Mountains (southern Italy): Another example of resetting of monazite ages in high-grade rocks. *Int. J. Earth Sci.* **2011**, *100*, 107–123. [CrossRef]
82. Cirrincione, R.; Fazio, E.; Fiannacca, P.; Ortolano, G.; Pezzino, A.; Punturo, R. The Calabria-Peloritani Orogen, a composite terrane in Central Mediterranean; Its overall architecture and geodynamic significance for a pre-Alpine scenario around the Tethyan basin. *Period. Mineral.* **2015**, *84*, 701–749. [CrossRef]
83. Fazio, E.; Fiannacca, P.; Russo, D.; Cirrincione, R. Submagmatic to solid-state deformation microstructures recorded in cooling granitoids during exhumation of late-variscan crust in north-eastern sicily. *Geosciences* **2020**, *10*, 311. [CrossRef]