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Assessment of the Didactic Potential of Geomorphosites: A Study Case in Spain and Italy

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Abstract

Studying Geography and Geology in formal education involves learning about landforms, landscapes, and the importance of preserving Natural Heritage. Geomorphosites are valuable resources with significant educational potential, as they can help students understand Earth's history, appreciate Natural Heritage, and recognize their cultural and historical connections to the territory. By analyzing the curricular contents of the educational systems in Spain and Italy, this research proposes a novel method, focused on formal education, to assess the didactic potential of geomorphosites. The assessment is based on (i) how representative geomorphosites are of physical processes, (ii) their potential to support interdisciplinary learning, (iii) the availability of didactic materials, and (iv) the possibility of applying field techniques. The results revealed varying levels of didactic suitability among the analyzed geomorphosites, with Ulaca Hill (Spain) and Nirano mud volcanoes (Italy) having the highest didactic potential, also allowing evaluation of their relevance across different educational stages. The application of the methodology in both the Spanish and Italian contexts, with minor adjustments, showed that this approach is readily adaptable to other educational systems. Overall, this study provides a transferable framework for integrating geomorphological heritage into formal teaching, promoting place-based learning and fostering awareness and conservation of Natural Heritage.

Keywords: geography; geology; geomorphosites; assessment method; didactic potential; Italy; Spain

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1. Introduction

Geomorphosites have been defined as geomorphological landforms that are of particular importance for understanding the Earth's history. They are spatially delimited and clearly distinguishable from their surroundings [1,2]. The geomorphic features of a territory serve as the foundation for habitats and landscapes, influencing human development and cultural elements, while geomorphological processes shape the Earth's surface. Geomorphosites are not only important for the understanding of the Earth's history but also have significant cultural, educational, and economic value in terms of geoconservation, landscape valorization, and land management. This geomorphological heritage serves as a natural resource that can be used for educational and tourism purposes, as highlighted by various authors [3–12]. This underscores the potential of geomorphosites as valuable territorial resources. In this context, the main aim of this paper is to develop a novel method for evaluating the educational potential of geomorphosites. In fact, geomorphosites, as part of the geoheritage, are a key resource for geoeducation and geotourism, which are closely linked and mutually supportive [11]. Geoeducation helps raise awareness of geodiversity and geoheritage, e.g., influencing tourist interests, and constitutes a crucial pillar of the geoscience community, as witnessed by numerous international initiatives. Among these, the UNESCO Global Geoparks, established within the UNESCO International Geoscience and Geoparks Programme, stand out as a prime example. These have Earth Science education and sustainable development at their core and are often achieved through geotourism. Developing geotourism can enhance access to educational resources [11]. Education and interpretation have been central to geotourism discussions since the early 1990s, fostering awareness of Natural Heritage and conservation for sustainable development [11,13,14]. Education is a key component in various definitions and approaches to geotourism.

However, in the aforementioned works, the educational value of geomorphosites has been largely confined to dissemination and environmental education, primarily associated with geotourism. In contrast, there are relatively few examples of geomorphosites being used in formal educational activities [15,16], even though their educational potential is a valuable resource for creating educational activities and materials at various levels, starting from primary education. Geomorphosites are resources in terms of their geomorphological components and are therefore important for learning about the history of the Earth. They may be linked to history and culture, which is interesting for a comprehensive and complementary understanding of the environment. Therefore, geomorphosites constitute places particularly suited for field didactic activities. Once the importance of geomorphosites for education has been recognized, it is necessary to establish how they can be integrated into formal educational content. The didactic potential of geomorphosites would then be understood as the suitability of geomorphosites for teaching Earth Science disciplines within formal education. The potential of integrating geomorphosites into the academic curriculum depends directly on the educational system of each country, which is structured around a set of recommendations, laws, and annual programming to which teachers must adapt their classes. National or regional laws in each country regulate the curriculum content, competencies, and learning objectives of each subject by academic year in compulsory and post-compulsory education levels, from primary education to pre-university education, which may have different names in each country. To analyze the fitting of geomorphosites into the academic curriculum development, it is necessary to consult the content and learning objectives that students must acquire by law in subjects related to the Earth Sciences, such as Geology, Geography, Geomorphology, Natural Hazards, Hydrology, etc.

In this context, the main aim of this research is to propose a systematic method for assessing the didactic potential of geomorphosites, specifically designed for the Spanish educational system but potentially extendable to other national contexts. To explore this potential, Italy was selected as a comparative case due to its distinct educational structure and its alignment with European curricular guidelines. The study involved a comparative analysis of the Geography and Geology curricula in Spain and Italy, followed by the application of the method to selected geomorphosites in both contexts, in order to examine its suitability across different educational systems.

2. Geomorphosite Didactic Potential Assessment: Methodological Proposal

The proposed method is structured into three sequential steps: (i) inventory of geomorphosites, (ii) geomorphosite assessment, and (iii) didactic suitability assessment. These sequential steps are described in the following subsections.

2.1. Inventory of Geomorphosites

For an initial geomorphological contextualization, a study of the physical environment and geomorphology of the area under consideration is made by consulting maps and existing works. From this desk work, an initial list of potential geomorphosites is created. This list is then refined through field work, resulting in a definitive inventory of geomorphosites. To this end, on-site accessibility and visibility are taken into account, with an initial assessment by experts in the field. Each site is accompanied by a detailed descriptive card, illustrating the scientific, cultural, and use and management values by applying the method developed by Serrano and González Trueba [17]. The latter has been applied in several works in natural protected areas and mountain landscapes [18–21]. The geomorphosite is classified according to whether it is an Element (an isolated landform) or a Site (a set of landforms with the same geomorphological genesis) and whether it is Representative in its geomorphological context (there is more than one similar example) or Exceptional (it is the only example of a particular landform).

2.2. Geomorphosite Assessment

The geomorphosites are then evaluated numerically on a scale from 0 to 4, where 0 represents the lowest score, 2 is an average score, and 4 is the highest score. All criteria are considered to be equally important within each of the three main blocks of parameters (conditioning factors for its use, physical elements, and additional values). Physical elements carry the greatest overall score when evaluating their intrinsic scientific value (with 32 points), followed by factors that condition their use, which are fundamental for any educational and/or geotourism or dissemination application (with 28 points), and, finally, additional values (with 16 points). The selection of evaluation criteria is based on widely accepted methodologies in the scientific community working on the assessment of geosites and geomorphosites [3,5,7,17,19–21]. Experts, who are selected based on their expertise in geomorphology and their familiarity with geomorphosite assessment method, assign the most appropriate scores within this range (from 0 to 4). The assessment relies on predefined criteria (cf. Table 1) and expert discussion, using detailed numerical and objective parameters to minimize the potential subjectivity of the method. The assessment criteria considered for geomorphosites are presented in Table 1 and summarized below.

a. Factors conditioning their use, considering their accessibility, fragility, seasonality, the intensity of the physical activity required to access the site, visibility of the geomorphosite, current uses, and legislation.
b. Assessment of their physical elements (intrinsic scientific value), including their geological and hydrological variety, landforms, active processes, weathering, and biodiversity.
c. Assessment of any additional values, considering landscape view (the view of the landscape from the geomorphosite depending on the degree of visibility), cultural elements (the number of examples of both tangible and intangible cultural heritage), anthropic influence (evaluates the degree of anthropic transformation of the territory in which the geomorphosite is framed), and economic value of the site (the presence of economic activities related to the geomorphosite or the territory in which the geomorphosite is located. Examples: active tourism companies, livestock farming, forestry).

The results of the assessment allow comparisons to be made between the selected geomorphosites and, in addition, to identify the most distinctive attributes of each geomorphosite.

Table 1. Geomorphosite assessment method.

Parameters	Criteria	Evaluation Scores
1. Conditioning factors for its use	Accessibility	0: no path 2: loose rock path 4: well-defined path
	Fragility (risk of degradation)	0: high (the geomorphosite is already degraded) 2: moderate (the geomorphosite is in process of degradation) 4: low (no degradation)
	Seasonality	0: can be visited less than 3 months per year 2: can be visited 3–6 months per year 4: can be visited all the year
	Intensity of physical activity (distance and elevation gain)	0: >15 km and +1.000 m 2: <10 km and +500 m 4: <5 km and <500 m
	Visibility of the geomorphosite	0: covered visibility 2: medium visibility 4: full visibility
	Current uses	0: no use 2: occasional use 4: frequent use
	Legislation	0: no legislation 2: in development 4: strong protection
	TOTAL (up to 28)	
2. Physical elements	Geology	0: one geological era 2: two geological eras 4: three or more geological eras
	Rocks (igneous, sedimentary, and metamorphic)	0: less than two 2: between two and four 4: five or more
	Superficial landforms	0: there are not superficial landforms 2: one or two 4: three or more
	Sedimentological cascade	0: no evidence 2: one example 4: two or more examples
	Weathering (chemical, physical, or biological)	0: no evidence 2: one example 4: two or more examples
	Active processes	0: no active processes 2: one example 4: two or more examples
	Biodiversity	0: no evidence 2: one example 4: two or more examples
	Hydrology	0: no liquid or solid water 2: one example 4: two or more examples
	TOTAL (up to 32)	
3. Additional values	Landscape view	0: no landscape view, landscape entirely covered by natural or anthropogenic features; 2: landscape view enclosed (e.g., by vegetation or other elements of the natural environment); 4: wide landscape and panoramic view, no obstacles to observation
	Cultural elements	0: no existence 2: one example 4: more than one example
	Anthropic influence	0: dominance of nature, space little or not at all modified by humans 2: rural/natural space partially modified by humans 4: anthropogenic influence dominates over natural influence
	Economic value	0: no economic activities 2: one economic activity 4: more than two economic activities
	TOTAL (up to 16)	

2.3. Assessment of the Didactic Suitability

Based on the results obtained in step 2, the didactic evaluation is performed for those geomorphosites that received a positive assessment in the previous phase. In this context, a positive assessment is defined as the attainment of at least 50% of the total score derived from the conditioning factors for its use, physical elements, and additional values, corresponding to a minimum score of 38 out of 76.

The aim is for geomorphosites to be used as resources for teaching Geography, Earth Science, Environmental Science, or Geology at different educational levels—primary, secondary, and higher education (see Table 2). Therefore, the curricular contents of each subject related to geography, geology, geomorphology, and the environment should be consulted. Geomorphosites represent physical processes, their relationship with the territory, human activity, and cultural heritage, so, depending on the intrinsic scientific value (physical elements assessed in Table 2) and added values of each geomorphosite, they may be more or less suitable for different educational levels. A geomorphosite with a very complex geomorphological content may only be suitable for secondary and higher education stages (e.g., a hanging syncline), while simpler landforms with the presence of cultural elements may be suitable for teaching from the primary stage (e.g., a river valley). The method also evaluates the availability of didactic materials, such as activity sheets for students or geoheritage guides for teachers, the possibility of applying field techniques (e.g., creating topographic profiles, vegetation pyramids, etc.), and the relationship with other school subjects.

Table 2. Assessment of the didactic suitability of geomorphosites.

Parameters	Criteria	Evaluation Scores
Didactic suitability assessment	Primary education suitability	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum
	Secondary education suitability	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum
	Higher education suitability	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum
	Relation with other disciplines	0: no relationship 2: related with social-science disciplines 4: related to other science disciplines
	Suitable material for formal education	0: no existence 2: presence of didactic material for formal education (e.g., activity sheets for students, geoheritage teaching guides for teachers) 4: didactic projects are under development
	Fieldwork techniques	0: no field techniques 2: possibility to apply some field techniques 4: possibility to apply several techniques
	TOTAL (up to 24)	

Likewise, each criterion is scored from 0 to 4, obtaining a numerical result that allows comparison between the didactic potential of the geomorphosites and selection of those with more potential for the design of didactic activities or routes.

3. Spanish and Italian Education Systems and Curricular Contents

The Spanish education system consists of general education and special education. General education (Table 3, A. Spain) includes early childhood education (0–5 years, not compulsory), primary education (6–11 years, 6 grades), compulsory secondary education (12–15 years, 4 grades), and baccalaureate (16–17 years, 2 grades). Vocational training and university education are also part of the general education system. Special regime teachings encompass artistic, language, and sports education.

Table 3. Geomorphology-related subjects in Spanish and Italian education systems.

Organization and Legislation		Geomorphology-Related Subjects	
A. Spain	Primary (6 academic years) Decree 38/2022, of 29 September, establishing the organization and curriculum of primary education in the community of Castilla y León.	Natural Science	1st to 5th year
		Social Science	3rd to 6th year
	Secondary (4 academic years) Decree 39/2022, of 29 September, establishing the organization and curriculum of compulsory secondary education in the Autonomous Community of Castilla y León	Geography and History	1st year
		Biology and Geology	1st, 3rd, and 4th year
	Baccalaureate (2 academic years) Decree 40/2022, of 29 September, establishing the organization and curriculum of the baccalaureate in the Community of Castilla y León.	Geography	2nd year
		Geology and Earth Sciences	2nd year
B. Italy	Primary (5 academic years) + First-grade secondary (3 academic years) Decree No. 254 of 2012, National guidelines for the primary and first grade secondary	Geography	1st to 5th year (primary) and 1st to 3th year (first-grade secondary)
		Science	1st to 5th year (primary) and 3th year (first-grade secondary)
	Second-grade secondary (5 academic years) Decree No 211 of 2010, National indications on the specific learning objectives for the activities and lessons included in the curricula foreseen for secondary school courses	Geography and History	1st and 2nd year
		Natural Sciences (Earth Sciences)	1st and 2nd year. 5th year in scientific itinerary

The education system is governed by the Organic Law on Education 3/2020 (LOMLOE) at the national level, except for university education, which falls under the Organic Law on the University System 2/2023 (LOSU). The system follows a decentralized state model, with educational competences divided between the Government and the Autonomous Communities. The state law sets the minimum requirements for each educational stage, while the Autonomous Communities develop their own curricula based on these guidelines. Therefore, Spain has seventeen different curriculum designs, one for each Autonomous Community.

In Castilla y León, three laws regulate the curricular content by educational level: primary education, secondary education, and baccalaureate. These laws specify the curriculum for each subject, outlining the competencies, evaluation criteria, and content for each course.

Unlike Spain, the Italian education system has a nationally legislated curriculum. The state establishes general rules and essential education levels through national guidelines, although each school and teacher can adapt their content based on the socio-economic and territorial context of their educational institution.

The Italian education system is organized into four main levels (Table 3 B. Italy): (1) the integrated system from zero to six years (preschool, not compulsory); (2) the first cycle of education, which includes primary school (6–11 years, 5 grades) and lower secondary school (11–14 years, 3 grades); (3) the second cycle of education (14–19 years, 5 grades), consisting of upper secondary school and vocational training; and (4) higher education (+19 years), which includes university education, higher artistic, musical, and dance education, and institutes of technology.

Decree No. 254 of 2012 establishes the national guidelines for the curriculum of early childhood education and the first cycle of instruction, up to the age of 14. The curriculum areas are defined in these national guidelines, with Geography and Science included in the first cycle (primary and lower secondary education).

Specific curriculum content for the second cycle of instruction, including upper secondary education (high school) and technical and vocational institutes, is outlined in Decree No. 211 of 2010. The subjects to be studied each year and the number of hours are detailed in the annexes for each specialization. In high schools, students aged 14 to 19 can choose from different educational paths: artistic, classical, linguistic, musical, scientific, and humanities. History and Geography are studied in the first two years across all paths, while Natural Sciences (Biology, Chemistry, and Earth Sciences) are typically studied in the first two years in most paths and throughout all five years in others (Scientific and Humanities).

When analyzing learning contents in Castilla y León (Table 4), Geography is introduced in secondary education and connected to History. In primary school, students learn about geomorphology and geology in Natural Science and Social Science subjects. The subject of Natural Science continues in secondary education with Biology, Geology, Physics, and Chemistry, but not Geography. Natural Science focuses on understanding the environment and fostering sustainable practices. Geography is part of Social Science, which explores geographical, historical, economic, and sociological aspects. The goal in both subjects is for students to develop a sustainable relationship with their environment. In secondary education, Geography and History are combined into one subject, alternating between Geography and History lessons each year.

The primary school curriculum for Natural Science includes the study of Natural Heritage, the natural landscapes of Castilla y León, and landforms. It also involves contact with the natural environment and outdoor activities, including field trips. In Social Science, students also study landscapes, physical elements, and the geographical diversity of Europe. These topics are also part of the Geography curriculum at secondary school, specifically in the first year. Additionally, in the subjects of Biology and Geology, students deal with a range of topics related to geomorphology and geology, including landscapes, landforms, rocks, minerals, and geological processes. These topics are covered during the first, third, and fourth years of secondary school. In the baccalaureate program, students chose an educational path that may include courses in Geography and Geology and Earth Sciences during their second year. These courses are based on the study of landforms and geomorphological analysis in Geography and Natural Heritage and geodiversity in Geology and Earth Sciences.

Table 4. Contents related to geomorphology in the Geography and Natural Sciences subjects of the Castilla y León (Spain) educational system.

Level	Subjects	Contents and Compentencies
Primary education	Natural Science	First year: Contact with nature through nearby natural spaces. Interest and enjoyment of outdoor activities. Care, respect, and empathy towards living beings and the environment in which they live. Local Natural Heritage, use, enjoyment, care and conservation.
		Second year: Natural landscapes of Castilla y León, characteristics and peculiarities.
		Third year: Natural heritage in Castilla y León. Natural Protected Areas in Castilla y León, their use, care and conservation. Most relevant landforms. Elementary classification of rocks.
		Fifth year: Basic classification of rocks and minerals. Basic geological processes of landform formation. Natural heritage as an asset and resource, care and conservation. Natural Protected Areas in Spain.
	Social Science	Third year: Climate and landscape. Relationship between climatic zones and the diversity of landscapes.
		Fourth year: Earth and natural disasters. Elements, movements, and dynamics that occur in the universe and their relationship with certain physical phenomena that affect the Earth and have an impact on daily life and the environment.
		Fifth year: Landscapes and landforms. Characteristics of the main landscapes of Castilla y León. The natural environment. The geographical diversity of Spain.
		Sixth year: The natural environment. The geographical diversity of Europe.
Secondary education	Geography and history	First year: Basic components and landforms, as well as processes that shape the Earth's surface. Wealth and value of Natural Heritage.
	Biology and Geology	First year: Rocks and minerals. Classification of rocks (sedimentary, metamorphic, and igneous). Geodynamic and geochemical models. Earth movements.
		Third course: Internal and external geological agents. Landforms modeling. Characteristic landforms of Castilla y León.
		Fourth year: Global effects of the dynamics of the geosphere through plate tectonics. External and internal geological processes. Landforms and landscape, importance as resources and factors involved in their formation and modeling. Geological stratigraphic columns and geological histories reflecting the application of the principles of the study of Earth history.
Baccalaureate	Geography	Second year: Spanish landforms. Peninsular and island relief units. Characteristics and location. Geomorphological factors. Physical factors and diversity of landscapes and ecosystems. Analysis of geomorphological, bioclimatic, edaphic, hydrological, and human-activity-related conditioning factors and prevention of associated risks.
	Geology and Earth Sciences	Second year: Geological and environmental heritage of Castilla y León. Assessment of its importance and the conservation of geodiversity. External geological processes (weathering, erosion, transport, and sedimentation). Landforms. Influence of geological agents, climate, and the properties and relative disposition of the predominant rocks. Castilla y León landforms.

Sources: Decree 38/2022, Decree 39/2022, and Decree 40/2022, Castilla y León regional Government.

Regarding the curricular contents in Italy (Table 5), in primary and first-grade secondary school, Geography is presented as the quintessential cross-curricular subject, with the aim of teaching students about the relationships between human societies and the planet they inhabit, as well as the processes of transformation of the natural environment, whether natural or caused by human activity. Geography is necessary at this stage to develop active citizenship competence, which involves students getting closer to their nearest territory. Through this approach and the study of the landscape, the goal is to raise awareness at this stage about inherited natural and cultural heritage. The curriculum establishes an initial approach to the territory through direct exploration. Field trips are therefore presented as a didactic necessity and obligation for the subject of Geography. In Science, the emphasis is on observation, research, and the experimental processes of the scientific method. This subject encourages students to ask questions, design experiments, and build models and for research to take place outside the classroom, including in natural spaces.

Table 5. Competencies and learning objectives related to geomorphology in the Geography and Natural Sciences subjects of the Italian educational system.

Level	**Subject**		**Contents and Competencies**
Primary and Secondary in the first grade	Geography		Recognize and name the main physical geographical “objects” (rivers, mountains, plains, coasts, hills, lakes, seas, oceans, etc.). Recognize the features of different European and global landscapes, comparing them in particular with Italian landscapes, significant physical elements, and historical, artistic, and architectural characteristics as natural and cultural heritage that must be protected and valued.
	Natural Sciences		Respect and appreciate the value of the social and natural environments. Recognize, through field research and concrete experiences, the main types of rocks and the geological processes from which they originated. Understand the structure of the Earth and its internal movements (plate tectonics); identify seismic, volcanic, and hydrogeological risks in the student’s region.
Secondary in the second grade (Liceo)	First two years	Geography and History	Understanding of the complex relationships between environmental conditions and socioeconomic and cultural characteristics. Describe transformation processes and morphological and climatic conditions. In the construction of didactic itineraries, the main themes to be considered are the landscape, environment, and society.
		Natural Sciences	Delves into the explanatory framework of the movements of the Earth and the geomorphological study of the structures that make up the Earth’s surface (rivers, lakes, glaciers, seas, etc.).
	Scientific, Human Sciences	Natural Sciences	References to mineralogy, petrology (rocks), and phenomena such as volcanism, seismicity, and orogeny are introduced, examining the transformations related to them. Complex meteorological phenomena and models of global tectonics are studied.

Sources: Decree No. 254 of 2012 and No. 211 of 2010, Italian Government.

The learning objectives for first-grade primary and secondary school for Geography and Science subjects focus on geomorphology and geology: studying the physical elements of the territory, landscapes, geological processes, geomorphological risks, and the importance of protecting Natural Heritage. This continues in the second cycle of instruction, where all pathways involve learning about the relationships between the environment and the territory, describing morphological and climatic processes and conditions in Geography. In Natural Sciences, students learn about tectonics and landforms. Students in the Scientific and Humanities pathways receive more specific training on mineralogy, petrology, orogeny, and global tectonics.

Furthermore, Decree No. 211 of 2010 states that for all pathways in the second cycle of secondary education, Earth Sciences content (Natural Sciences) should be developed in coordination with Geography, and teachers should adapt the content based on the territorial context of the educational center.

4. Study Area: Spanish and Italian Geomorphosites

The two study areas, the Sierra de la Paramera in Spain and the Northern Apennines between Reggio Emilia and Modena Province in Italy, and specifically the assessed geomorphosites, have been selected for their geomorphological significance and representativeness at both local and regional scales. They also exemplify landforms typologies, combining high accessibility with notable cultural heritage, and have strong connections with the local population.

4.1. Sierra de la Paramera, Castilla y León, Spain

The study area corresponds to Sierra de la Paramera and Serrota (Ávila, Castilla y León, Spain), which is located in the western sector of Sistema Central. It constitutes a mountain range alignment developed in an east–west direction, with heights of over 2000 m a.s.l. (Zapatero peak, 2158 m a.s.l.; Serrota, 2294 m a.s.l).

This mountainous area is made up of large Variscan granites and metasediment rocks of Paleozoic origin. During the Alpine orogeny, it was faulted and divided into blocks. The structural relief is defined by the fractures that limit the tectonic blocks, thus conditioning their altitude and orientation or crushing or breaking the rocks. The Sierra de la Paramera and La Serrota are the mountain ranges that stand out between two tectonic valleys, Amblés to the North and Alberche to the South [22].

It is a tectonic relief made up of pop-up and pop-down geological structures with tectonic valleys (grabens) and tectonic blocks (horsts) distinctive of the Central System [23–25]. The relief is defined by the sequence of the Amblés tectonic valley to the north, a flat surface at an average altitude of 1500 m a.s.l., the Paramera de Ávila, and the tectonic blocks of Serrota and Zapatero ranges to the south.

Two geomorphosites have been selected for assessment of their didactic potential: Ulaca granite Hill (Figures 1 and 2) and the Manqueospese Castle on granitic rocks (Figures 1 and 3). These are described in the subsections below.

4.2. Foothills of the Northern Apennines Between Reggio Emilia and Modena Province, Italy

The Italian study area is located along a foothill stretch of the Northern Apennines mountain chain between the Provinces of Modena and Reggio Emilia in the Emilia-Romagna Region, Northern Italy.

From a geological perspective, the study area reflects the complex events characterizing the Northern Apennine orogenesis. This orogenesis involved the progressive closure of the Piemont-Liguria Ocean, a branch of the Tethys ocean, beginning in the Early Cretaceous [26,27] and culminating in the collision between the Adriatic and European continental plates during the middle Eocene. Consequently, the region features a complex geological structure comprised of folded and faulted units of marine (Ligurian units) and continental (Tuscan and Umbria units) origins. From the upper Eocene until the Lower Miocene, sediments were deposited in a marine environment atop the Apennine accretionary prism, forming the Epiligurian succession.

The landscape of the study area is primarily shaped by the action of running water and greatly influenced by its structural and tectonic features. Additionally, human activity has impacted the region, particularly between the 1960s and 1990s. In recent years, growing interest in environmental protection has led to the implementation of plans, projects, and legislation aimed at preserving and enhancing the area's valuable natural elements and landscapes [28,29].

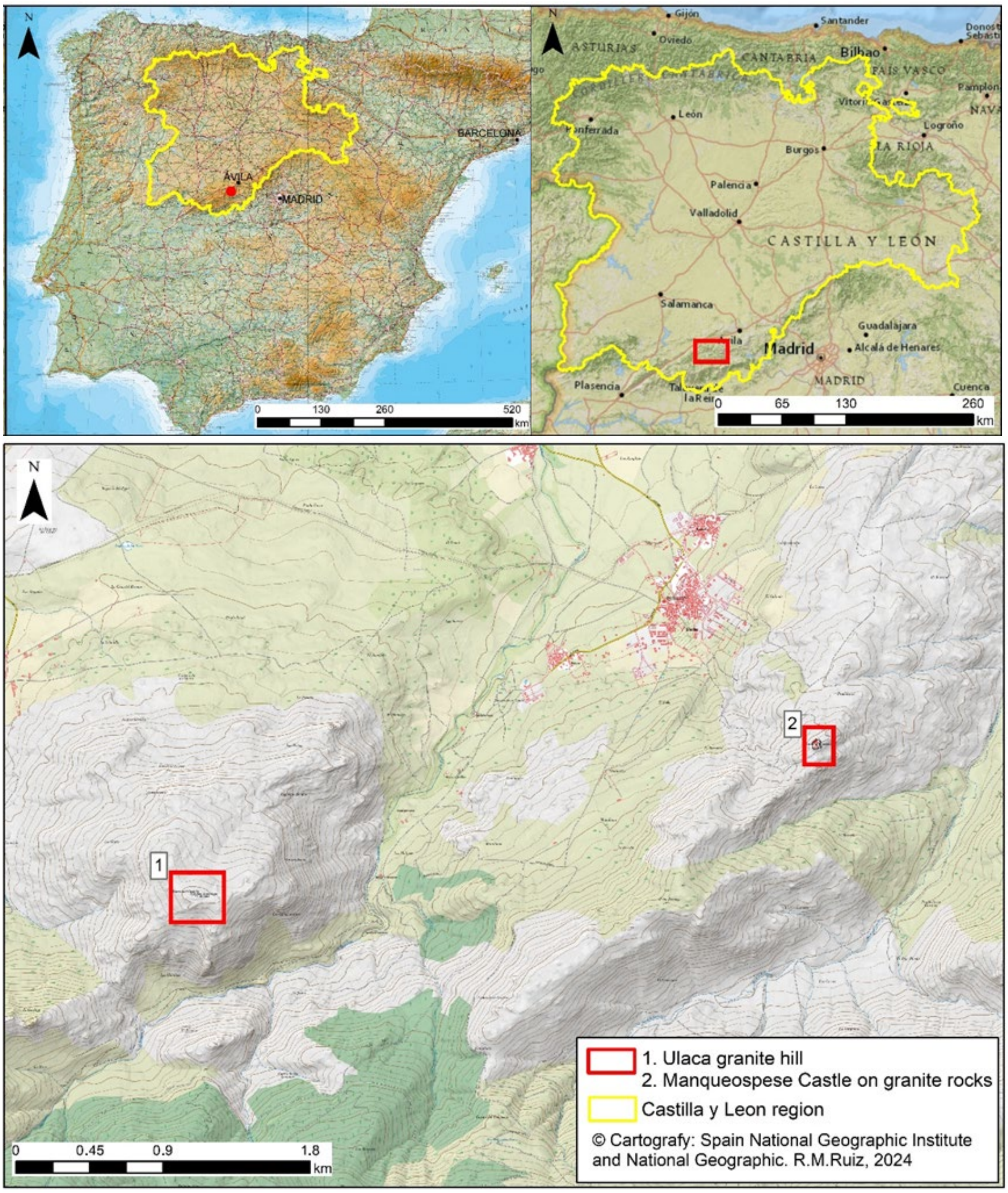

Figure 1. Ulaca granite hill and Manqueospese Castle on granite rocks, located in Ávila, Castilla y León, Spain.Cartography: Spain National Geographic Institute and National Geographic. R.M.Ruiz-Pedrosa, 2024 [21].

In this geological and geomorphological context, three sites were selected within the investigated area for their high didactic potential. These sites are the Nirano mud volcanoes, included in the regional and national geosite inventory, the Castellarano synclinal flysch, and Pescale faulted canyon, which are included in the official geosite inventory of the Emilia Romagna Region (Figure 2). These three geomorphosites are described in the subsections below.

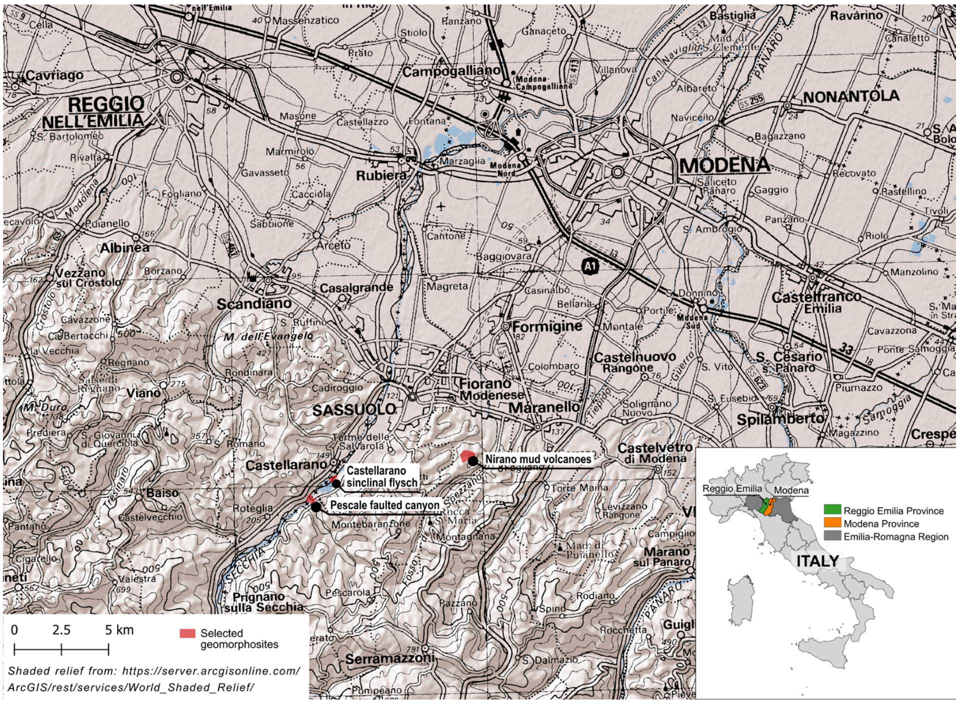

Figure 2. Location of the three sites under investigation for the evaluation of their didactic potential within the Northern Apennines, Emilia-Romagna Region (Northern Italy). The sites include the Castellarano synclinal flysch, the Pescale faulted canyon, and the Nirano mud volcanoes.

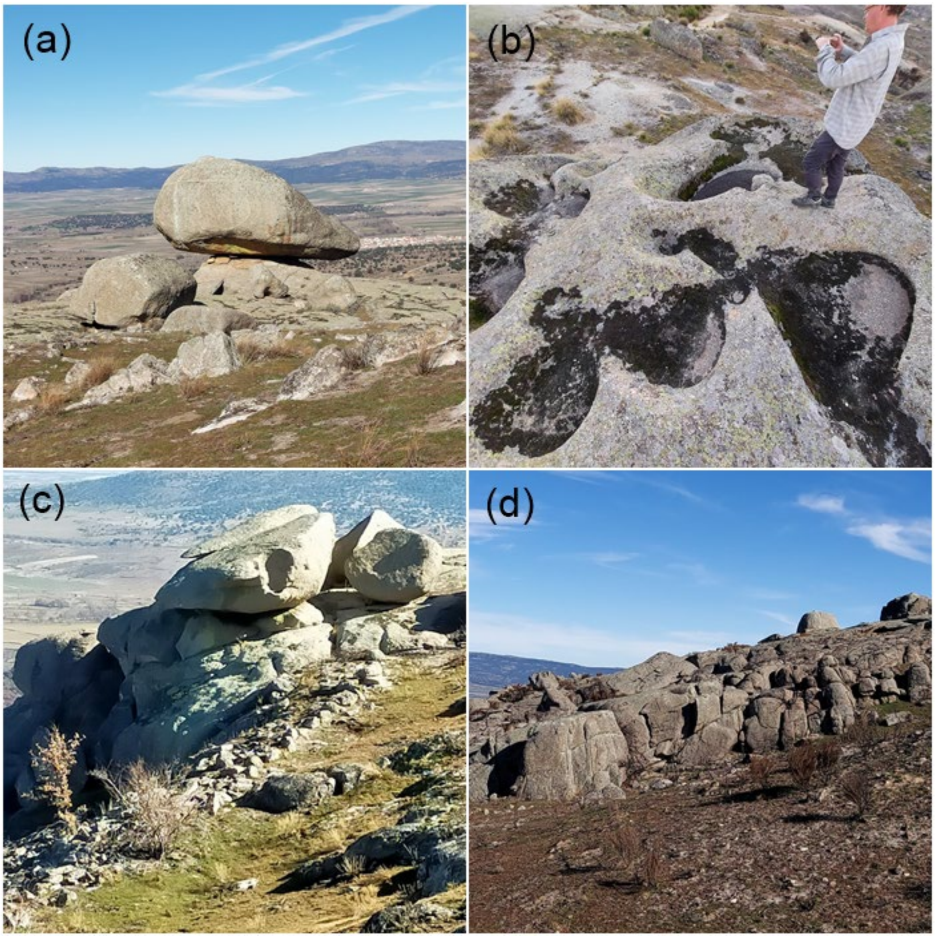

Figure 3. Granite landforms in Cerro de Ulaca. (**a**) Balancing granite rock, (**b**) granite gnammas, and (**c**,**d**) tors. Photographs: Rosa María Ruiz-Pedrosa and Enrique Serrano.

5. Results

5.1. Inventory of Geomorphosites

5.1.1. Sierra de la Paramera, Castilla y León, Spain

Ulaca Granite Hill

Situated on the top of El Castillo hill (40°31′46.4″ N, 4°53′09.1″ W), it is a fortified settlement that was occupied at the end of the Iron Age (centuries III-I B.C.) by the pre-Roman Celtic tribe of the Vettones. The walled settlement was home to more than 1000 inhabitants [30,31]. The archaeological site is placed on a half horst located on the northern slope of the Sierra de la Paramera (Figure 2, Table 6). Landforms are defined by the weathering of granite, which decomposes the rock and leaving quartz grains with a granular appearance (for more details on landform formation in this area, see [22]), known as grus. The granitic landforms are dominant, with a multitude of major landforms (nubbins, granite boulders, domes, half domes, tors, etc.) and minor landforms (gnammas, tafoni, balancing rocks) in excellent states of conservation. The top of the half horst is an excellent panoramic viewpoint to observe the relief and landscape towards the granite crests of the Picos Zapateros (Figure 3) and the tectonic valley of Amblés.

Table 6. Ulaca Granite Hill identification sheet.

Identification	**Name: Ulaca Granite Hill**	**Site: Ulaca Vettone Hillfort**	**N° 1 Altitude: 1508 m**
Location	**Town: Villaviciosa, Ávila**	**Coordinates: 40.525181; −4.883174**	
Geomorphological description	TYPE	Site	
		Representative	
	Genesis	Granite weathering	
	Morphology: Description, morphostructures, erosion	El Castillo rocky hill, on the northern side of Sierra de la Paramera horst, on the border with Amblés valley to the north and the Picuezo river to the south. There are outstanding examples of granite landforms including domes, tors, balancing granite rocks, and gnammas. The presence of granite rocks strongly influences the types of geomorphological features characterizing this area. Hydrolysis, i.e., the chemical alteration of granite caused by water, is frequent in the study area, decomposing the rock into clays (formed by feldspars and micas) and leaving the quartz grains loose and with a granular appearance known as grus. In Ulaca, there is an outstanding granite landform with a multitude of major and minor granitic landforms that stand out for their high visibility.	
	Active processes	Granite weathering, erosion, gravitational processes	
	Chronology	Miocene–nowadays	
	Main geomorphological interest	Granitic landforms	
	Secondary geomorphological interest	Germanic relief	
	Geomorphosite attribution	**Granitic**	
Additional values	Landscape	Wide view of the valley	
	Cultural elements	Ulaca Hillfort	
	Economic	Tourist	
	Social	Recreational and cultural. Celebration of Celtic traditions	
	Conservation	Good (geomorphology)	
	Actual uses	Cultural, touristic, and archaeological	
	Infrastructure	Information panels on the hill road (poorly signposted)	
	Impacts	Roads affected by post-fire processes, including soil erosion (August 2021)	
	Legislation	Cultural protection: Despoblado de Ulaca	
Accessibility	Walking distance	2 km from parking (45 min)	
	Elevation gain	300 m	
	Security	Marked path	

The interest of the site relies on its size, which is more than 70 ha; its walls, which surround the hill and reach 3 km in length, making it one of the largest fortifications of this period in the Iberian Peninsula [32]; and the complex organization shown by the craft workshops and the cemetery located outside the walls [33]. The site also preserves important material remains and exceptional and well-preserved Celtic structures such as the settlement (oppidum), with the remains of more than 250 dwellings, the altar (rock sanctuary), the keep, the sauna, and the quarries [31,34,35]. The Ulaca Hillfort was designated a Historic-Artistic Site in 1931; it has been an Asset of Cultural Interest since 1986, and in 1994 it was defined as an Archaeological Area (Spanish Historical Heritage Law).

The Ulaca Granite Hill is a geomorphosite with moderate accessibility and excellent visibility of active granite weathering processes, as well as outstanding cultural heritage, making it a geomorphosite with potential didactic value at all levels.

Manqueospese Castle on Granite Rocks

The geomorphosite is located on a high point of the Paramera, to the south of Mironcillo village to the west of the Garganta river (40°32′03.7″ N, 4°50′19.1″ W). It offers views of the Amblés valley and Ávila city. The castle is adapted to the orography and the granite relief, taking advantage of a castle kopje-type tor as part of its walls. The construction is completely encased in the granite (Figure 4, Table 7). As in the case of the Ulaca Hillfort, the granite landforms are the result of the weathering and there are tors and gnammas in the surrounding area.

Table 7. Manqueospese castle on granitic hill identification sheet.

Identification	**Name: Manqueospese Castle on Granitic Hill**	**Site: Manqueospese Castle**	**Nº 2** / **Altitude: 1372 m**
Location	**Town: Mironcillo, Ávila**	**Coordinates: 40.34306; −4.838682**	
Geomorphological description	TYPE	Site	
		Representative	
	Genesis	Granite weathering	
	Morphology: Description, morphostructures, erosion	Castle located on a high point of the Paramera in the south of Mironcillo, to the west of the Garganta river. Adapted to the orography and the granite relief, using large granite blocks as part of its walls, the construction is completely encased in the granite. It offers views of the Amblés graben as well as of Avila city.	
	Active processes	Granite weathering, erosion	
	Chronology	Miocene–nowadays	
	Main geomorphological interest	Granite landforms	
	Secondary geomorphological interest	Germanic relief	
	Geomorphosite attribution	Granitic	
Additional values	Landscape	Wide view of Amblés valley and Ávila city	
	Cultural elements	Manqueospese Castle	
	Economic	Tourism	
	Social	Cultural, recreation	
	Conservation	Rubbish, debris	
	Actual uses	Cultural, tourist	
	Infrastructure	Road	
	Impacts	Fire (August 2021)	
	Legislation	Cultural protection: Manqueospese Castle	
Accessibility	Walking distance	3 km from Mironcillo (40 min)	
	Elevation gain	250 meters	
	Security	Marked path	

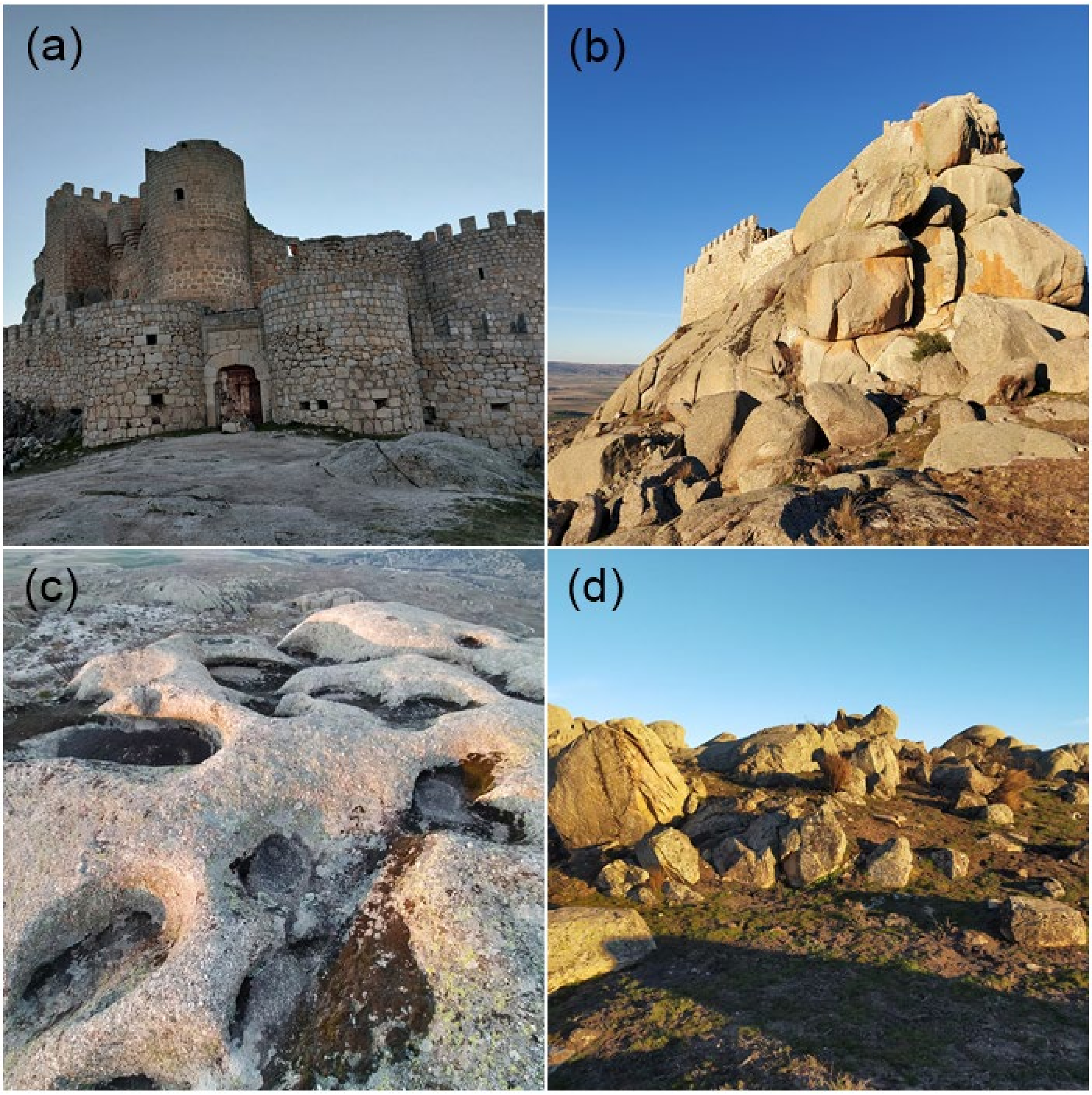

Figure 4. Granite landforms in Castillo de Manqueospese. (**a**) Castle, (**b**) granite castle walls, (**c**) gnammas in the surroundings, and (**d**) granite rocks. Photographs: Rosa María Ruiz-Pedrosa and Enrique Serrano.

The castle was built between the 14th and 15th centuries and declared an Asset of Cultural Interest on 3 June 1931; the locals say that the castle gets its name from a love story between a lady and a knight, her parents opposing their romance and the castle being their meeting place. Today, the castle is privately owned.

As in Ulaca, accessibility is moderate due to rocky paths, although the spectacular granite landforms and views of the landscape and morphostructure give it educational potential, probably at secondary-school level.

5.1.2. Foothills of the Northern Apennines Between Reggio Emilia and Modena Province, Italy

Nirano Mud Volcanoes

The Salse di Nirano Natural Reserve was established in 1982 and covers an area of 209 hectares within the municipality of Fiorano (Modena Province, Northern Italy). Renowned as one of Italy's most significant mud volcano sites (Figure 5, Table 8), these cone-shaped landforms emit cold mud mixed with salty water and hydrocarbons. The mud volcanoes at Salse di Nirano are among the most well-preserved in Europe and have been subject to extensive study over many centuries. Since the 17th century, they have attracted scientific attention from notable geoscientists such as Spallanzani [36] and Stoppani [37].

Subsequent research has focused on various aspects including the geological, geomorphological, and biological characteristics of the area [38,39]. Recently, they were selected as a site for developing educational virtual field trips that highlight their geoheritage values [40].

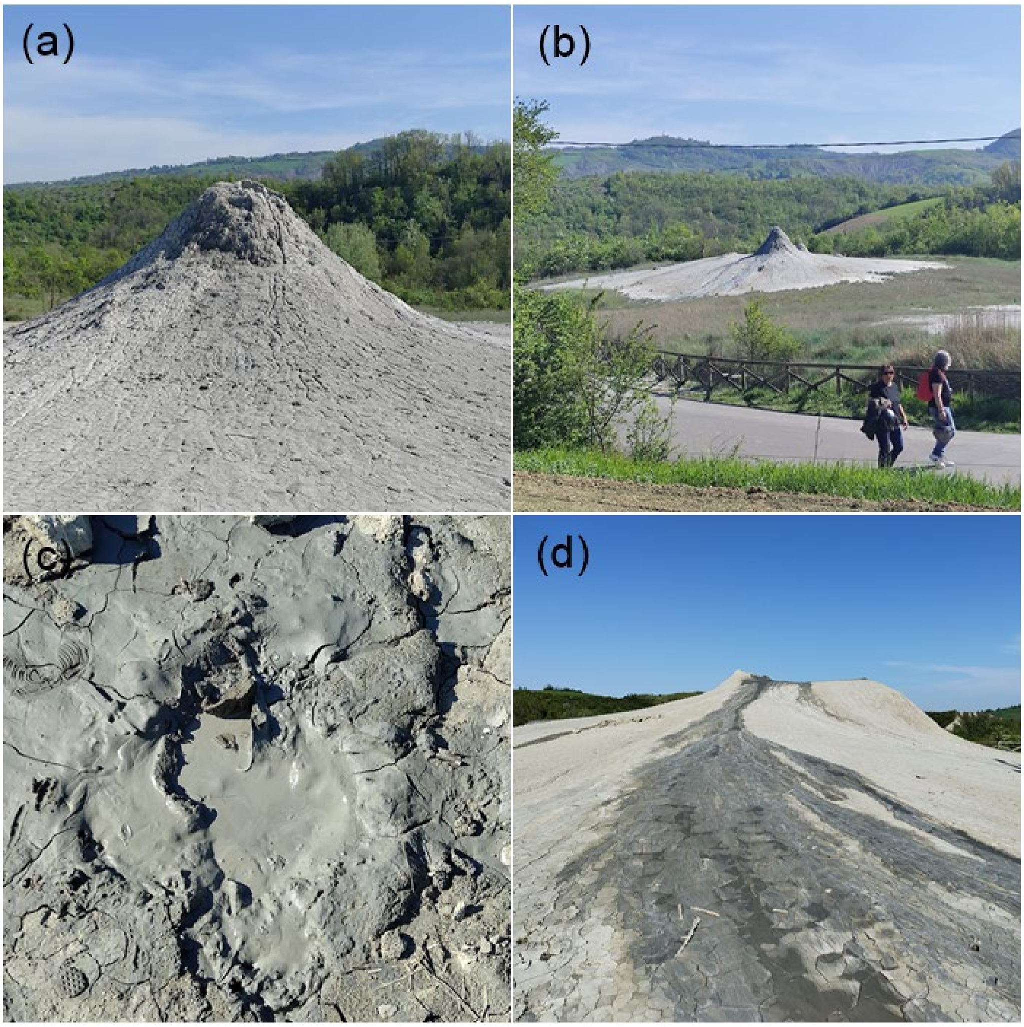

Figure 5. Nirano mud volcanoes: (**a**,**b**) Edifices of the mud volcanoes, (**c**) detail of mud volcano on active ground, and (**d**) active cone stream detail.

According to the most updated studies, the emissions of cold mud are produced by salty and muddy water from late Miocene-Pleistocene marine depositsrising to the surface along two systems of faults that are oriented in the SW-NE and NW-SE directions [41].

The total number of volcanoes is not fixed, as the mud-ejecting apparatuses are constantly evolving. The main mud volcano structures comprise five edifices located within an elliptical depression, encircled by steep slopes, which is interpreted as a caldera formed by a collapse resulting from the expulsion of mud from beneath the surface [41]. The area surrouding the mud volcanoes displays a typical badland morphology shaped in Plio-Pleistocene marine sediments consisting mainly of grey-bluish silts, clays, and marly clays. This landscape is marked by steep-sided V-shaped gullies separated by narrow, sharp ridges as a result of the combined action of running water and gravitational processes.

The reserve boasts a well-developed tourist infrastructure and also includes a visitor center and an ecomuseum that not only provide informative and explanatory materials to tourists but also host educational activities for promoting the valorization of the Reserve, including didactic visits for schools. These two facilities are housed in restored ancient structures, thereby enhancing the architectural, historical, and cultural value of the site.

Table 8. Nirano mud volcanoes identification sheet.

Identification	**Name: Nirano Mud Volcanoes**	**Site: Salse di Nirano**	**N° 2**
			Altitude: 225 m
Location	**Town: Fiorano, Modena**	**Coordinates: 44.513618; 10.823523**	
Geomorphological description	TYPE	Site	
		Exceptional	
	Genesis	Endogenous	
	Morphology: Description, morphostructures, erosion	The Nirano mud volcanoes are located in the Modena Apennines, in the Emilia sector of the Pede-Apennine, characterized by a fold-and-thrust relief originating from the consumption of the Piemont-Liguria Ocean. These emissions of cold mud are produced by the rising to the surface of salty and muddy water from late Miocene-Pleistocene marine deposits, along two systems of faults, SW-NE and NW-SE, showing clear alignment. The Nirano Site covers an area of 75,000 m^2 and is located at the bottom of a caldera, hosting individual or multiple cones. The number of volcanoes is not steady, as the mud-ejecting apparatuses are constantly evolving.	
	Active processes	Active; new vents are constantly created whereas others become dormant	
	Chronology	Miocene–nowadays	
	Main geomorphological interest	Mud volcanism	
	Secondary geomorphological interest	Badlands	
	Geomorphosite attribution	Mud volcanism	
Additional values	Landscape	Wide viewpoints	
	Cultural elements	Intangible	
	Economic	Tourism and restaurants	
	Social	Cultural and recreation	
	Conservation	Among the best conserved in Europe	
	Actual uses	Excursionism, dissemination	
	Infrastructures	Fountains, recreative areas, birdwatching, visitor center Cà Tassi, ecomuseum Cà Rossa, parking area, observation points	
	Impacts	Low, there are protection measures for anthropic impacts	
	Legislation	Regional Nature Reserve of the Nirano mud volcanoes, 1982. Network Natura 2000 “Salse di Nirano”	
Accessibility	Walking distance	1.5 km from parking to Salse di Nirano	
	Elevation gain	50 m	
	Security	Marked accessible trail	

The high accessibility of the Reserve, the vent active processes, and the availability of educational materials and activities confirm that the Nirano mud volcanoes have high didactic potential for all levels of education.

Castellarano Synclinal Flysch

This geomorphosite consists of a vertical outcrop of extensive turbidite strata that are prominently visible downstream of the Castellarano dam along the Secchia River. Following this turbidite geological formation, pelagic sedimentation is preserved and exposed in the area, consisting primarily of clays. In recent times, these outcrops were exhumed due to severe erosional processes that affected the alluvial deposits within the Secchia riverbed (Figure 6, Table 9). The removal of fluvial sediments by river action was exacerbated by the construction of the dam. The exhumed geological formations introduced above bear witness to the paleogeography from the Late Cretaceous to the early Paleocene in the Piedmont-Liguria Ocean.

Figure 6. Castellarano flysch and related interpretative panel.

Therefore, the site is of great scientific interest, as the exceptional quality of the outcrops allow for detailed observation of both stratigraphic and sedimentological features within the strata. Moreover, the site holds considerable importance from a structural and tectonic perspective. The outcropping formations are part of a rock fold of regional extent, providing valuable insights into the geological history of the area. Additionally, the site displays the recent geomorphological evolution of the Secchia River. The erosion and deposition processes have been profoundly altered by human intervention, significantly reshaping the fluvial landscape.

Table 9. Castellarano synclinal flysch identification sheet.

Identification	**Name: Castellarano Synclinal Flysch**	**Site: Castellarano Dam**	**N° 4**
			Altitude: 145 m
Location	**Town: Castellarano**	**Coordinates: 44.503425; 10.730474**	
Geomorphological description	TYPE	Element	
		Exceptional	
	Genesis	Structural	
	Morphology: Description, morphostructures, erosion	Vertical outcrop in the Secchia riverbed of Cretaceous flysch and Paleocene pelagic sediments of the Piemont-Ligurian Ocean, which were folded during the Alpine orogeny, forming a syncline fold of regional extension. The erosion of the alluvial sediments exacerbated by the construction of a dam caused these substrates to be exposed along the course of Secchia River.	
	Active processes	Active, fluvial erosion	
	Chronology	Cretaceous–present day	
	Main geomorphological interest	Structural	
	Secondary geomorphological interest	Fluvial	
	Geomorphosite attribution	Structural	
Additional values	Landscape	Covered visibility	
	Cultural elements	-	
	Economic	Agriculture (irrigation), hydroelectric power plant	
	Social	-	
	Conservation	-	
	Actual uses	Hiking, cycling	
	Infrastructures	Dam	
	Impacts	Dam	
	Legislation	Geosites of the Emilia-Romagna Region	
Accessibility	Walking distance	200 m from parking	
	Elevation gain	-	
	Security	Asphalt path	

The high accessibility of Castellarano synclinal flysch, as well as the presence of interpretive panels and active river processes, make it a possible site for educational activities, although it will be necessary to evaluate which educational levels it is most suitable for.

Pescale Faulted Canyon

Near Pescale, the Secchia River forms a narrow gorge bordered by subvertical cliffs approximately 30 m high that are composed of Lower Miocene marine carbonate rocks (Figure 7, Table 10). The presence of a regional normal fault system has facilitated river incision, forming a deep canyon known as Pescale Strait. Due to the narrowing of the Secchia River, this fluvial stretch is particularly impetuous during periods of high discharge. A notable example of this is the remains of an old barrage (Figure 7b) destroyed by the flood wave of 1966, concurrent with extreme rainfall events that affected the Italian Peninsula in the autumn of that year. Beyond this "bottleneck," the riverbed widens again. Fluvial deposits identified atop Pescale hill suggest that this is an inactive fluvial terrace of the Secchia River. According to the literature, this terrace was active 140,000 years ago ([42] and the references therein).

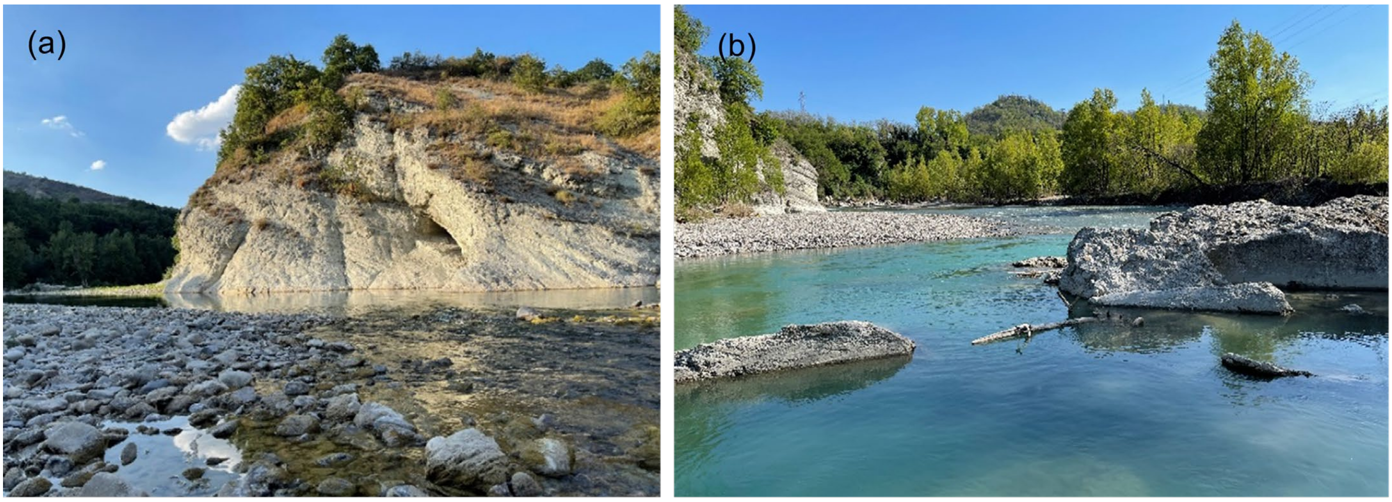

Figure 7. (**a**) The Pescale cliff bordering the right side of Secchia River. (**b**) Concrete remnants of a former barrage at the Pescale Strait, destroyed in the flood event of 1966.

Table 10. Pescale faulted canyon identification sheet.

Identification	**Name: Pescale Faulted Canyon**	**Site: Castellarano (Pescale Locality)**	**N° 5**
			Altitude: 200 m
Location	**Town: Castellarano**	**Coordinates: 44.494720; 10.716228**	
Geomorphological values	TYPE	Site	
		Exceptional	
	Genesis	Fluvial-structural	
	Morphology: Description, morphostructures, erosion	The narrow limestone canyon is a distinctive feature of the Secchia River as it passes through Pescale, resulting from the river being confined within a normal fault system with regional extentions. The riverbed is composed of Miocene limestone. An inactive fluvial terrace dated as 140,000 years old was identified at an elevation of some 30 m above the current riverbed at the Pescale site, providing information on the changes of the Secchia River.	
	Active processes	Fluvial erosion	
	Chronology	Cenozoic–present day	
	Main geomorphological interest	Fluvial	
	Secondary geomorphological interest	Structural	
	Geomorphosite attribution	Fluvial	
Additional values	Landscape	No landscape view	
	Cultural elements	Neolithic settlement, former dam, former heliotherapy colonies	
	Economic	-	
	Social	Heliotherapy (20th century)	
	Conservation	-	
	Actual uses	Hiking	
	Infrastructures	Interpretative panels	
	Impacts	-	
	Legislation	Geosites of the Emilia-Romagna Region	
Accessibility	Walking distance	2 km from Castellarano dam	
	Elevation gain	-	
	Security	Marked path	

The proximity of the Pescale cliff to the Secchia River and its unique geomorphological features, which create a natural bulwark, have attracted human settlements since prehistoric times. Notably, during the Neolithic period, it hosted a significant human settlement, as evidenced by exceptional archaeological findings. Roman remnants have also been discovered at the site.

In more recent history, during the first half of the 1900s, fluvial bars composed of white sand and pebbles were used to host heliotherapy colonies for locals. These colonies, established for the therapeutic use of sunlight—then believed to offer health benefits—were popular in the early 20th century. The Pescale site still preserves traces of this social aspect of the period; in fact, preserved changing cabins can be found along the nearby cycling path, serving as a witness to the local customs of the past.

Despite the Pescale faulted canyon being easily accessible, its low scenic value and greater geomorphological specialization suggest that its educational potential is more suitable for upper secondary school levels.

5.2. Assessment Results

For the assessment of the didactic suitability, it was necessary to adapt the method with respect to what is presented in Table 2. In Spain, there are three educational stages (primary, secondary, and higher education—each scored a maximum of 4 points, totaling 12), while in Italy there are only two (primary and lower secondary school and Lyceum, totaling 8). As a result, the maximum total score assignable for assessing the didactic suitability of each Spanish geomorphosite is 24, while for Italian geomorphosites it is 20.

Four geomorphosites received high scores in terms of the conditioning factors for its use (Table 11: first row). Italian geomorphosites are characterized by high accessibility, with low physical effort required to reach them (cf. physical intensity criteria) owing to good trails and tourist infrastructure, especially in Salse di Nirano Natural Reserve. Italian geomorphosites are also protected by strong environmental legislation, which contributes to their moderate fragility. Spanish geomorphosites are characterized by medium accessibility, as the paths are rocky and sometimes poorly signposted. In addition, they do not have an official environmental protection status themselves, although they are located near a Habitat Directive site within the Natura 2000 Network. The five geomorphosites can be visited throughout the year.

Table 11. Geomorphosites assessment results (for extended version see Table 12).

	Ulaca Granite Hill	Manqueospese Castle on Granite Rocks	Nirano Mud Volcanoes	Castellarano Synclinal Flysch	Pescale Faulted Canyon
1. Conditioning factors for its use. Total (up to 28)	18	20	26	25	24
2. Physical elements. Total (up to 32)	16	16	19	19	19
3. Additional values. Total (up to 16)	12	12	12	10	8
4. Didactic suitability. Total (up to 24 in Spain/20 in Italy)	22	12	20	18	18

Green means high value (>2/3 score). Yellow means medium value (between 1/3 and 2/3 score). There is no low value (<1/3 score).

Table 12. Geomorphosites assessment sheet. A: Ulaca granite Hill; B: Manqueospese Castle on granite hill; C: Nirano mud volcanoes; D: Castellarano synclinal flysch; E: Pescale faulted canyon.

		A	B	C	D	E
1. CONDITIONING FACTORS FOR ITS USE	**Accessibility** 0: no path 2: loose rock path 4: well-defined path	2	2	4	4	4
	Fragility (risk of degradation) 0: high (the geomorphosite is already degraded) 2: moderate (the geomorphosite is in process of degradation) 4: low (no degradation)	2	4	2	2	2
	Seasonality 0: can be visited less than 3 months per year 2: can be visited 3–6 months per year 4: can be visited all the year	4	4	4	4	4
	Intensity of physical activity (distance and elevation gain) 0: >15 km and +1.000 m 2: <10 km and +500 m 4: <5 km and <500 m	2	4	4	4	4
	Visibility of the geomorphosite 0: covered visibility 2: medium visibility 4: full visibility	4	4	4	4	3
	Current uses (excursions, interpretation. . .) 0: there is not 2: occasional use 4: frequent use	2	0	4	3	3
	Legislation 0: there is not 2: in development 4: strong protection	2	2	4	4	4
	TOTAL (UP TO 28) =	**18**	**20**	**26**	**25**	**24**
2. PHYSICAL ELEMENTS	**Geology** 0: one geological era 2: two geological eras 4: three or more geological eras	0	0	2	2	2
	Rocks (igneous, sedimentary and metamorphic) 0: there is not 2: up to four 4: five or more	2	2	2	2	2
	Superficial landforms 0: there is not 2: one or two 4: three or more	4	4	2	2	2
	Sedimentological cascade 0: no evidence 2: one example 4: two or more examples	0	0	2	4	4
	Weathering (chemical, physical, or biological) 0: no evidence 2: one example 4: two or more examples	4	4	1	2	2
	Active processes 0: no active processes 2: one example 4: two or more examples	2	2	4	2	2
	Biodiversity 0: no evidence 2: one example 4: two or more examples	0	0	4	1	1
	Hydrology 0: no liquid or solid water 2: one example 4: two or more examples	4	4	2	4	4
	TOTAL (UP TO 32) =	**16**	**16**	**19**	**19**	**19**
3. ADDITIONAL VALUES	**Landscape view** 0: no landscape view, landscape entirely covered by natural or anthropogenic features 2: landscape view enclosed, e.g., by vegetation or other elements of the natural environment 4: wide landscape and panoramic view, no obstacles to observation	4	4	4	2	3
	Cultural elements 0: no existence 2: one example 4: more than one example	4	4	4	0	3
	Anthropic influence 0: dominance of nature, space little or not at all modified by humans 2: rural/natural space partially modified by man 4: anthropogenic influence dominates over natural influence	4	4	2	4	2
	Economic 0: no economic activities 2: one economic activity 4: more than two economic activities	0	0	2	4	0

Table 12. *Cont.*

		A	B	C	D	E
	TOTAL (UP TO 16) =	**12**	**12**	**12**	**10**	**8**
4. DIDACTIC SUITABILITY assessment **A: SPAIN**	**Primary education suitability**					
	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum	4	0			
	Secondary education suitability					
	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum	4	2			
	Higher education suitability					
	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum	4	4			
	Relation with other disciplines					
	0: no relationship 2: related with social-science disciplines 4: related to other science disciplines	4	4			
	Suitable material for formal education					
	0: no existence 2: presence of didactic material for formal education (e.g., activity sheets for students, geoheritage teaching guides for teachers) 4: didactic projects are under development	2	0			
	Fieldwork techniques					
	0: no field techniques 2: possibility to apply some field techniques 4: possibility to apply several techniques	4	2			
	TOTAL (UP TO 24) =	**22**	**12**			
B: ITALY	**First cycle suitability (primary + first grade secondary)**					
	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum			4	4	4
	Second cycle suitability (Liceo)					
	0: the values represented by the geomorphosite are not included in curriculum 2: is considered in a cross-cutting manner 4: is compulsory in the curriculum			4	4	4
	Relation with other disciplines					
	0: no relationship 2: related with social-science disciplines 4: related to other science disciplines			4	4	4
	Suitable material for formal education					
	0: no existence 2: presence of didactic material for formal education (e.g., activity sheets for students, geoheritage teaching guides for teachers) 4: didactic projects are under development			4	2	2
	Fieldwork techniques					
	0: no field techniques 2: possibility to apply some field techniques 4: possibility to apply several techniques			4	4	4
	TOTAL (UP TO 20) =			**20**	**18**	**18**

The results regarding the physical elements (intrinsic scientific value) of geomorphosites are moderate (Table 11, second row). The lowest scores were assigned to the Spanish geomorphosites, which received identical totals. Although they clearly represent very visible weathering processes and spectacular landforms, they lack elements related to biodiversity. The three Italian geomorphosites received high scores, all standing out as good examples of active hydrological and erosional processes, as well as processes of transportation, sedimentation, and weathering.

The additional values (Table 11, third row) have the highest score at Ulaca, Manqueospese, and Nirano mud volcanoes, each rated with a score of 12. In addition to their high scenic value, these sites also feature numerous cultural elements. Castellarano synclinal flysch and Pescale faulted canyon received medium scores for the additional value, with Pescale faulted canyon scoring the lowest due to the absence of anthropic influence and economic activities in the immediate surroundings.

Regarding didactic suitability (Table 11, forth row), all geomorphosites have a high value except Manqueospese. In Spain and Italy, subjects related to geomorphology, geology, landscape, and Natural Heritage are supposed to be studied in all educational courses, so four geomorphosites are suitable for all levels of both educational systems. Manqueospese was considered less appropriate for primary education due to the complexity of its geological and geomorphological features, as well as for its low additional value. The five geomorphosites offer high potential for multidisciplinary teaching, enabling the integration of both Social Sciences and Natural Sciences in field-based educational activities. Only the Italian geomorphosites are equipped with interpretive panels, visitor centers, and school visit programs. Ulaca and Manqueospese, being in an unplanned and unmanaged natural areas, do not have these facilities. In the assessment of the didactic potential, factors influencing use, scientific value, additional value, and didactic suitability should be considered. In this case, four of the geomorphosites have high didactic suitability and Manqueospese has medium value. The selected geomorphosites have medium scientific value yet retain high didactic potential. It is important to note that high values for physical element criteria should not be the sole determinant of didactic potential. Geomorphosites with low accessibility, high fragility, and limited curricular relevance are not recommended for inclusion in educational field trip proposals, even if their geological and geomorphological scientific value is high. In contrast, geomorphosites that meet all the criteria outlined in the proposed method are recommended for selection.

The two geomorphosites with the greatest didactic suitability are Nirano mud volcanoes in Italy and Ulaca in Spain. The Nirano mud volcanoes site, in particular, stands out for its well-established tourist and dissemination initiatives. It hosts ongoing educational and outreach activities, offers well-developed infrastructure for accessibility, and serves as excellent examples of active geological and geomorphological processes that are easily visible in the field, with high landscape and cultural value. The same applies to Castellarano, where the municipality is putting a lot of effort into the development of educational initiatives (such as interpretative panels, guided excursions, and Earthcache); however, the tourist infrastructure and educational initiatives are not as developed as for the Nirano mud volcanoes site. There is no educational equipment of any kind at Ulaca, although its educational potential continues to be high owing to the high additional value of the archaeological site, the spectacular landforms, and its high degree of multidisciplinarity. It is particularly useful to apply the method in geomorphosites that, while not yet developed for educational use, still have didactic potential for school visits, such as Manqueospese Castle on granite hill and Pescale faulted canyon.

6. Discussion

The Spanish and Italian education systems, despite differences in legislation and subjects, have very similar curricular content in the study of Earth Sciences, giving geomorphosites a high didactic potential in both systems. While education legislation in Spain is mainly determined by individual regions, in Italy it comes from the state. It is not surprising that the content is so similar, as both countries are members of the European Union and their education laws address EU recommendations. The most relevant EU recommendation in education legislation is the Council Recommendation of 22 May 2018 on key competences for lifelong learning, which includes eight competences: 1. Literacy; 2. Multilingual competence; 3. Mathematical and science, technology, and engineering competence; 4. Digital competence; 5. Personal, social, and learn-to-learn competence; 6. Citizenship competence; 7. Entrepreneurship competence; and 8. Cultural awareness and expression competence. The competence related to geomorphosites is science, defined as the ability to explain the natural world through observation and experimentation, as well as the student's ability to explain the influence of humans on the natural environment. However, these recommendations are limited in terms of Earth Science education, as they do not provide further details on the definition of the natural world or address Natural Heritage awareness—though cultural awareness is mentioned. Despite this, both Spain and Italy have emphasized the study of Natural Heritage and raised awareness about its protection on their curriculum.

As previously discussed, the curricular contents are broadly similar in both countries. In particular, there is a strong emphasis on the concept of Natural Heritage and the study of landscapes and landforms, not only at regional and national levels but also at a European level. However, the way Earth Science content is distributed across subjects differs significantly between the two systems. This contrast made the comparison between Spain and Italy meaningful for evaluating the adaptability of the proposed method, given their shared adherence to the European educational framework but distinct internal structures. In Italy, Geography is taught from the early years of primary school and continues until the second year of the upper secondary school, after which it is no longer part of the core curriculum. In contrast, in Spain, Natural Sciences are taught in primary school and Geography is introduced in secondary school, where it is always linked to History. Spanish Geography curricula tend to emphasize human geography, with basic concepts of landforms and Natural Heritage introduced only in the first year of secondary education, while the Geology subject includes most of the contents related to Earth Sciences and Physical Geography. Only in the Spanish baccalaureate is the Geography subject dedicated to an in-depth study of physical geography. Therefore, in the Spanish education system, Geography is mainly focused on its human and socioeconomic aspects. In contrast, Italian students are introduced to physical geography from the early years of primary education and in upper secondary school. Regardless of their chosen track, they study physical geography in the first two years of schooling. Additionally, in the Italian educational system, Geology is not a separate subject but is part of Natural Sciences. Based on this configuration, it seems that Geology is given more importance to in Spain, while Geography is emphasized in Italy.

However, despite the importance of Geography and Geology, the reality is that the curriculum contents are not always followed, and both subjects have minimal weight in the Italian and Spanish educational systems. It is common for teachers who teach Geography to be historians and those who teach Geology to be biologists, so often of physical geography and geology content is overlooked due to the lack of time in for course development or a lack of teacher geological and geomorphological knowledge, as some authors have pointed out [43,44]. The result is confusion among students, who do not know what geography or geology are, let alone achieve the learning objectives related to geomorphology (landscapes, landforms) or geology (orogeny) by the end of their educational stage. In short, students' education in Earth Sciences is very limited, making it difficult to raise awareness of Natural Heritage. In this context, it seems more than necessary to strengthen the role of Earth Sciences in the educational system. The inclusion of didactic contents on geomorphosites in teaching programs can undoubtedly be of great help.

The proposed method for assessing didactic potential was designed for the Spanish educational system, which is divided into primary, secondary, and baccalaureate levels, each governed by its own specific regulations. Therefore, the fourth step of the method includes a scoring system that accounts for these three levels individually. However, part of the research aimed to explore whether the proposed method could be applied beyond the Spanish educational system and, if so, what modifications would be necessary for such adaptation. This would allow the method to serve as a useful tool for the evaluation of geoheritage educational potential in different national contexts. In adapting the method to the Italian educational system, it was necessary to account for its two-level structure: the first cycle of education, which includes primary and lower secondary, and the second cycle of education, which includes upper secondary education. Adapting the method to this structure required only minor adjustments, mainly a simplification of the last step into two levels. This suggests that the proposed method is flexible and can potentially be extended to other educational systems.

In both the Spanish and Italian educational systems, the goal of learning through experimentation and interaction with the environment is established from early levels of education. This objective aligns with field trips to natural spaces where students can reinforce Earth science concepts taught in the classroom, enhancing learning and motivation [45]. In this context, geomorphosites can be valuable educational tools to improve the effectiveness of the teaching contents, supporting teachers and helping students not only in the learning process but also in raising awareness and appreciation of the Natural Heritage. The protection and, consequently, the sustainable use of geoheritage lies in this awareness and appreciation of Natural Heritage. Heritage that is not known cannot be valued, and heritage that is not valued cannot be protected. Therefore, a first step for raising awareness about geoheritage is formal education in educational institutions. This is recognized by UNESCO, with one of the Sustainable Development Goals (SDGs) being quality education, which conceives education as the key to achieving the rest of the SDGs, including goal number 15, Life on Land. This goal, which aims to protect and restore terrestrial ecosystems and therefore protect Natural Heritage, is directly related to geoeducation and geomorphosites. Earth science disciplines play an important role in the education of sustainability and geoheritage protection, and specifically in Geography, by encompassing natural and social sciences, providing a more holistic view of sustainability and laying the foundations for sustainable development [46,47]. In a time when geotourism is booming, proposals that guarantee sustainable use for the protection and dissemination of the knowledge of geomorphosites are more necessary than ever, as many authors have pointed out [3,48–56].

The proposed method not only evaluates the scientific and additional values of geomorphosites but also the factors influencing their use—such as accessibility, fragility, seasonality, visibility, current uses, and legislation—as other authors have done previously [3,5,56,57]. Focused on formal education, and not having been valued in other works to date, a thorough study of the educational legislation of the countries under study is added to the method, analyzing the curricula of the subjects in which geography-related content is taught. Regarding the didactic potential, geomorphosites such as the Nirano mud volcanoes, Castellarano synclinal flysch, and Pescale faulted canyon in Italy, and Ulaca Granite Hill and Manqueospese Castle on granite hill in Spain, have medium and high didactic potential due to their high scientific geological–geomorphological value, as well as their good accessibility and additional values, making them highly suitable for multidisciplinary teaching.

7. Conclusions

The teaching of Earth Sciences falls short of achieving the learning objectives and competencies set out in the European Union recommendations and the curricula of countries such as Spain and Italy. Currently relegated to subjects like History and Biology, students are not mastering the geology- and geomorphology-specific content, which hinders an appreciation of Natural Heritage as something to protect and conserve. Geomorphosites, which represent not only geological and geomorphological processes of high scientific value but also a cultural and territorial legacy, can be used as didactic resources that, through field trips, help reverse the marginalization of Earth Sciences in school systems. In addition, teaching about geomorphosites from an early age helps raise awareness about geoheritage and, therefore, promotes sustainable use of these places for their protection and conservation. The proposed method of didactic assessment of geomorphosites facilitates their incorporation into formal education in diverse educational systems. Through the analysis of legislation and curriculum content related to Earth Sciences subjects, which is innovative and has not been proposed in other methods, the suitability of geomorphosites as a matter of study in different educational levels can be established. After a detailed analysis of the legislation and the established learning objectives and contents in the curricula, the method is easily adaptable to different educational levels. Therefore, the method can be used by educators in different countries to incorporate geomorphosites into Earth Science teaching, thereby improving students' awareness of Natural Heritage and emphasizing the need to educate students on the sustainable use of geoheritage. The future must move towards effective collaboration between the Earth science research community, non-university educators, and public administrations, which should promote reforms to highlight the importance of teaching geological and geomorphological heritage and offer real support (funding and teaching resources) for field trips and teaching based on students' contact with their territory.

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