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ORIGINAL ARTICLE

Geosite Assessment for Geotourism Purposes: Case Study of Ida Madra Geopark, Türkiye

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Abstract
This study was conducted to evaluate some of the geosites in the Ida Madra Geopark for geotourism purposes. The Kubalikova (2013) method was used to assess the geosites for geotourism purposes. Using this method, 20 geosites were scored in five main categories and subcategories: scientific and ethical values, educational value, economic value, conservation value, and aesthetic value. Scores ranged from 9.00 to 18.25. The Kaz Mountain received the highest score, while the Taştepe basalt columns received the lowest. According to these results, geosites with higher scores attract more visitors. They also contribute more economically to the local community through geotourism. Efforts should also be made to address the shortcomings of low-scoring geosites, increase their geotourism capabilities, and ensure that the Geopark provides greater financial support to local communities through geotourism.

Keywords Geotourism · Geosite · Assessment · Ida madra geopark

Introduction

Tourism activities continue to expand and diversify, and one of the emerging concepts within this process is geotourism. Derived from the Greek word geo (earth), geotourism refers to the presentation of a geographical location—including its natural and cultural features—for tourism purposes. It is broadly defined as "tourism that sustains or enhances the geographical character of a place, its environment, culture, aesthetics, heritage, and the well-being of its residents" (Travel Industry Association of America & National Geographic 2003; Hose 2000). Geotourism is widely recognized as a significant component of sustainable tourism (Akıncı and Kasalak 2016l & Gül 2016; Doldur 2016).

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Since the 1990s, numerous methodologies have been developed to assess geosites in terms of their scientific, educational, aesthetic, economic, and conservation values. Early approaches include Panizza (2001), later refined by Coratza and Giusti (2005). Bruschi and Cendrero (2005) emphasized intrinsic scientific quality, economic potential, and conservation needs, while Serrano and Gonzalez-Trueba (2005) proposed criteria based on scientific, incremental, and management values. Pralong (2005) introduced a detailed method focusing on economic and cultural parameters, and Pereira et al. (2007) developed a comprehensive framework later expanded by Pereira and Pereira (2010). Reynard et al. (2007) highlighted the importance of detailed inventories and field studies, while Zouros (2005, 2007) incorporated geodiversity, ecological, cultural, and aesthetic values. Kubalíková (2013) synthesized these approaches into a widely adopted valuation table.

Over the past two decades, geosite assessment has become a prominent research field, with more than 440 studies indexed in the Web of Science. Case studies have been reported from Germany (Röhling and Schmidt-Thomé 2004), Greece (Fassoulas et al. 2012) China (Wang et al. 2015), Serbia (Tomić and Božić 2014; Tomić et al. 2020), Poland (Górska-Zabielska and Kamieńska 2017), Poland and Italy (Zwolinski et al. 2018), Indonesia (Suilo et al. 2020), Albania (Braholli and Menkshi 2021), the Andes

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(Carrión-Mero 2021), and Argentina (Salvadeo et al. 2025). These studies collectively demonstrate the growing recognition of geosite evaluation as a crucial tool for sustainable tourism planning. Moreover, Hose (2012) emphasized that fostering informed communities and supportive research environments is essential to ensure the long-term appreciation and protection of geosites. Despite this expanding body of research, comprehensive geosite assessments remain limited for many geoparks in Türkiye, particularly those integrating scientific, educational, economic, and conservation perspectives within a single framework.

Against this background, the present study investigates the geotourism potential of geosites within the Ida Madra Geopark, a region notable for its geological, natural, and cultural significance. To achieve this objective, the Kubalíková (2013) assessment method was selected due to its comprehensive structure and its integration of earlier evaluation approaches, particularly those proposed by Pralong (2005) and Pereira et al. (2007). This method is considered especially suitable for systematically evaluating geotourism potential and supporting sustainable geopark management strategies.

Study Area

The Ida Madra Geopark is located in northwestern Türkiye, encompassing the entire Balıkesir province, the districts of Ayvacık and Ezine in Çanakkale, and the Bergama district of İzmir. Its unique position along both the Marmara and Aegean coasts contributes to a diverse combination of natural and cultural landscape (Fig. 1).

The geopark hosts geosites of local, regional, national, and international significance, representing geological, geomorphological, natural, historical, and cultural heritage. In total, seven conceptual and eleven thematic hotspots have been identified (Fig. 2). These sites are notable for their scientific, aesthetic, geotourism, and educational values.

Characteristics of the Ida Madra Geopark

The Ida Madra Geopark is distinguished by its exceptional geoheritage, a direct reflection of its rich geological diversity. To better understand and interpret this diversity, the area's key features have been organized into conceptual and spatially significant categories, each highlighting unique geological phenomena.

Among the conceptual hotspots, several stand out for their scientific, educational, and aesthetic value. The Geopark hosts active travertine cones and chimneys, where ongoing carbonate deposition offers a living window into geological processes (Hafeli 1966). Complementing these are geothermal travertine cones and terraces, which demonstrate the dynamic interaction between geothermal activity and mineral formation. The region is also notable for hydrothermal mineral enrichment and metallogenic ore formation within the Tethyan Orogenic Belt, emphasizing its significance in regional mineralization and ore genesis.

The Geopark's tectonic structures, fault systems, volcanic features, and geothermal activity illustrate the complex geological evolution of western Anatolia, shaping both the landscape and its underlying geology (Altunkaynak and Yılmaz 1999; Hafeli 1966; Duru et al. 2004; Ercan et al. 1986). This rich geodiversity has long influenced human activity, as seen in ancient mining and quarrying sites, which reflect a deep and sustained interaction between culture and the Earth's resources. Another unique aspect is ignimbrite geoarchaeology, where dwellings carved directly into bedrock testify to the ingenuity of past societies adapting to the geological environment. Finally, the area's granite geology, geomorphology, and topography provide striking examples of landscape evolution, from rugged peaks to intricate rock formations.

Together, these conceptual hotspots make the Ida Madra Geopark a remarkable repository of geological knowledge, offering insights not only into Earth's history but also into the ways in which humans have engaged with and adapted to this dynamic environment.

The spatial distribution of geological, geomorphological, natural, and cultural features within the conceptual areas of the Geopark encompasses a diverse range of landscapes and geoheritage sites. The Hisaralan geothermal field is characterized by striking travertine chimneys, while the Simav Graben showcases hydrothermal mineral enrichment. In the Madra and Kozak region, granite formations and tor topography coexist with the traditions of Anatolian nomadic culture, creating a unique human–environment interaction. Along the coast, the Ayvalık islets reveal distinctive coastal geomorphology, whereas the ancient granite quarries at Kestanbol, associated with Alexandria Troas, reflect a rich historical heritage (Birkle and Satır 1994; Lazzarini 1987; Ponti 1995).Şahinderesi Canyon exemplifies the intersection of karst processes, geomorphological development, and geoarchaeological significance. Mount Ida stands out for its exceptional combination of geological features, mythological importance, and biodiversity. Industrial heritage is represented by the polymetallic mining sites of Balya and the marble quarrying legacy of Marmara Island, while the Kapıdağ Peninsula and Çataldağ areas highlight prominent granite topography and granite slabs, respectively. Together, these areas illustrate the Geopark's remarkable geodiversity and its intertwined natural and cultural landscapes.

Fig. 1 Location of Ida Madra Geopark (Study area)

Methods

This study covers a three-stage research process consisting of literature review, fieldwork and analysis of collected data. The first involved reviewing publications and studies related to the site and obtaining the necessary literature information.

The second phase involved fieldwork and observations to inventory potential geosites and examine their tourism-related features on-site, qualitative evaluation of preliminary features, select representative geological sites, and characterize stratigraphic, geomorphological, and accessibility characteristics. On-site fieldwork also

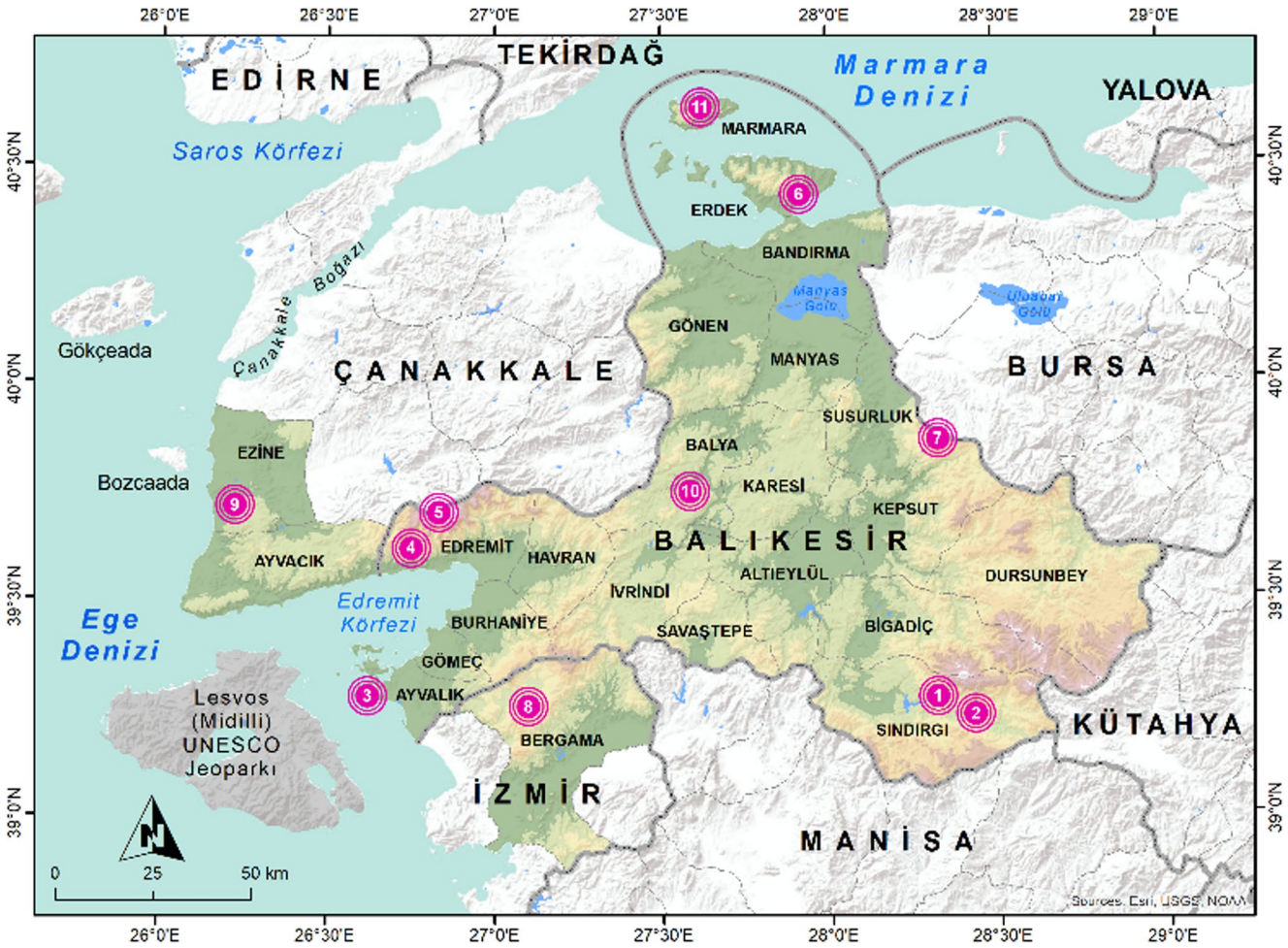

Fig. 2 Spatial Hotspots of the Ida Madra Geopark

included documenting the geological, geomorphological, natural, and cultural features of the geosites that could contribute to geoheritage value.

Finally, the identified geosites were quantitatively assessed using the Kubalíková (2013) method, integrating field observations with existing scientific data. The overall aim of this process was to determine how existing geoheritage resources could contribute to local development through geotourism.

Conceptually, key issues were identified based on the geological and geomorphological characteristics of the geopark as a geoheritage and their diversity. The location of geoheritage areas related to these conceptual issues, in other words, their spatial distribution, was then determined. In the final stage, geological, geomorphological, natural, and cultural features were identified as geosites within the conceptual and spatial domains. The criteria for determining geosites were primarily whether they reflected an event (volcanic, magmatic, mineralization, hydrothermalization, tectonic, sedimentological) that occurred during a specific period of Earth's history, and areas with these characteristics were tested as geosites. This study selected geosites that could contribute to geotourism. Their selection was based on scientific merit, visual appeal, accessibility, and potential to attract more people.

Field investigations were carried out using 1:25,000-scale topographic and geological maps. In addition, satellite imagery and unmanned aerial vehicle (UAV) images were utilized to support the identification and characterization of geosite features and to enhance spatial analysis.

Assessment of the Geosites

Within the diverse geological and geomorphological framework of the Ida Madra Geopark, a total of 45 geosites (Fig. 4) have been identified in previous studies according to UNESCO Global Geopark criteria. In the present research, all 45 geosites were initially reviewed to assess their geotourism potential. Based

on this preliminary evaluation, a representative subset of 20 geosites with higher geotourism relevance was selected and subsequently assessed in detail using the method proposed by Kubalíková (2013), Kubalikova and Kirchner (2016) . The sites were selected based on stratigraphic importance, geomorphological representativeness, accessibility, and educational potential.

The method assesses geosites in six categories (see also Table 1):

1. Scientific and intrinsic values (e.g., stratigraphic uniqueness, tectonic significance, representativeness).
2. Educational values (clarity of geological features, potential for interpretation and teaching).
3. Economic values (tourism potential, accessibility, contribution to local economy).
4. Conservation values (vulnerability, protection status, management needs).
5. Added values (cultural, historical, ecological associations).
6. Aesthetic values (visual appeal, landscape quality).

Each category is supported by sub-assessment questions, and scoring was conducted on a standardized scale (Table 1). Five independent experts (geologist, geomorphologist, tourism expert, geographer and archaeologist) applied the criteria to each geosite, and the final assessment index was calculated as the average of their evaluations.

In line with the workflow illustrated in Fig. 3, the study followed a systematic sequence:

- Inventory of potential geosites within the Ida Madra Geopark.
- Identification of sites with notable geoheritage and geotourism relevance.
- Qualitative assessment of preliminary attributes.
- Selection of twenty representative geosites.
- Characterization of stratigraphic, geomorphological, and accessibility features.
- Quantification through standardized scoring criteria.
- Numerical assessment of scientific, educational, economic, conservation, added, and aesthetic values.
- Analysis of results to produce comparative insights and highlight geotourism potential.

Evaluation process involved geologist, geomorphologist, tourism expert, geographer and archaeologist who are experts in their respective fields.

This structured and multidisciplinary approach ensured transparency, reproducibility, and consistency with international standards for geosite assessment.

Results

Geosite Inventory and Description

Based on the collected information, 20 geological sites were selected for detailed analysis. The selected sites possess unique geological, geomorphological, natural, and cultural characteristics. Figure 4 shows the locations of the selected sites. The general and geotourism-specific features of these geosites are also listed below.

GS1 - Kaz Mountain (Mt. Ida)

Mount Ida, with peaks exceeding 1,700 m, stands out for its combination of geological, geomorphological, cultural, and natural features. It represents significant geoheritage values, including tectonic evolution, metamorphism, and erosion processes. The site combines geological richness with cultural significance, making it one of the most important geosites of the Geopark (Fig. 4a, b).

GS2 - Kozak Granite Topography

The Kozak granitoid pluton is characterized by distinctive granitic landforms, including tors and large boulders (Fig. 4c). These features, set within extensive stone pine forests, form a unique landscape of high aesthetic appeal. Moreover, the site provides valuable insights into granite weathering processes, enhancing its scientific importance.

GS3 – Şahin (Hawk) Canyon.

Şahin Canyon was formed through tectonic uplift followed by deep incision into Mesozoic limestone, reaching depths of approximately 600 m. The canyon hosts a unique microclimate that supports endemic plant species. Owing to its well-preserved geomorphology, the site serves as an excellent example of valley development in carbonate rocks and is particularly valuable for geotourism and educational activities.

GS4 – Madra Granite Tor Topography.

Covering an area of approximately 500 km², the Madra granites display remarkable tor topography characterized by spheroidal boulders formed through exfoliation. Beyond its geomorphological significance, the site is also notable for its cultural continuity, as local communities continue traditional seasonal migration practices within this landscape (Figs. 4d and 5a).

GS5 - Tuzla Rainbow Rocks

The Tuzla geothermal field lies along an active fault zone and is hosted by rhyolite lava and pyroclastic deposits (Fig. 6e). Its vivid geothermal features highlight the tectonic and

Table 1 The criteria of geosite assessment (Based on Kubalikova 2013). The geosites were assessed according to 6 criteria: scientific and intrinsic values, educational values, economical values, conservation values, added values and aesthetic values

1 - Scientific and intrinsic values (maximum 4 points)		
Integrity	totally destroyed site	0
	disturbed site, but with visible abiotic features	0.5
	site without any destruction	1
rarity (number of similar sites)	more than 5 sites	0
	2–5 similar sites	0.5
	the only site within the area of interest	1
diversity (number of different partial features and processes within the geosite or geomorphosite)	only one visible feature/processes	0
	2–4 visible features/processes	0.5
	more than 5 visible features/processes	1
scientific knowledge	unknown site	0
	scientific papers on national level	0.5
	high knowledge of the site, monographic studies about the site	1
2 - Educational values (maximum 4 points)		
representativeness and visibility/clarity of the features/processes	low representativeness/clarity of the form and process	0
	medium representativeness, especially for scientists	0.5
	high representativeness of the form and process, also for the laic public	1
exemplarity, pedagogical use	very low exemplarity and pedagogical use of the form and process,	0
	existing exemplarity, but with limited pedagogical use	0.5
	high exemplarity and high potential for pedagogical use, goedidactics and geotourism	1
existing educational products	no products	0
	leaflets, maps, web pages	0.5
	info panel, information at the site	1
actual use of a site for educational purposes (excursions, guided tours)	no educative use of the site	0
	site as a part of specialized excursions (students)	0.5
	guided tours for public	1
3 - Economical values (maximum 3 points)		
accessibility	more than 1000 m from the parking place	0
	less than 1000 m from the parking place	0.5
	more than 1000 m from the stop of public transport	1
presence of tourist infrastructure	more than 10 km from the site existing tourist facilities	0
	5–10 km tourist facilities	0.5
	less than 5 km tourist facilities	1
local products	no local products related to a site	0
	some products	0.5
	emblematic site for some local products	1
4 - Conservation values (maximum 4 points)		
actual threats and risks	high both natural and atrophic risks	0
	existing risks that can disturb the site	0.5
	low risks and almost no threats	1
potential threats and risks	high both natural and athrophic risks	0
	existing risks that can disturb the site	0.5
	low risks and almost no threats	1
current status of a site	continuing destruction of the site	0
	the site destroyed, but now with management measures for avoid the destruction	0.5
	no destruction	1
legislative protection	no legislative protection	0
	existing proposal for legislative protection	0.5
	existing legislative protection (Natural monument, Natural reservation…)	1
5 - Added values (max. 2 points)		
Cultural values	no cultural features,	0
	existing cultural features but without strong relation to abiotic features,	0.5
	existing cultural features with the strong relations to abiotic features	1

Table 1 (continued)

1 - Scientific and intrinsic values (maximum 4 points)		
Ecological values	not important,	0
	existing influence but not so important,	0.5
	important influence of the geomorphologic feature on the ecologic feature	1
6 - Aesthetic values (max. 1.5 points)		
number of colours	one color	0
	2–3 colors	0.25
	more than 3 colors	0.5
structure of the space	only one pattern	0
	two or three patterns clearly distinguishable	0.25
	more than 3 patterns	0.5
viewpoints	none	0
	1–2	0.25
	3 and more	0.5

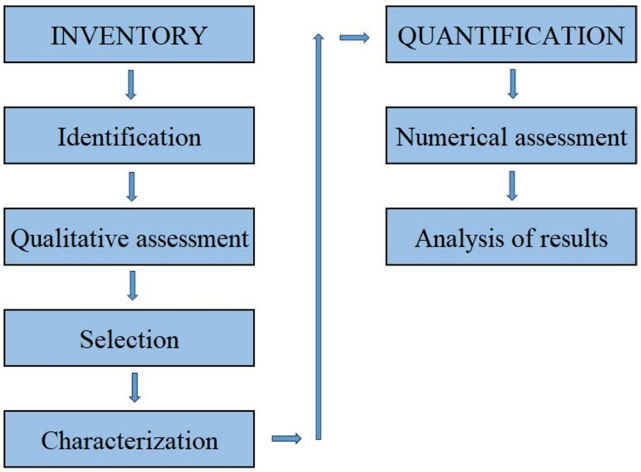

Fig. 3 Flow diagram of geosite assessment

volcanic activity of western Anatolia and represent significant geotourism and scientific value.

GS6 - Hisaralan Geothermal Field and Travertine Cones

Situated in the Sındırgı area, this geothermal field hosts actively forming travertine cones and terraces produced by thermal springs (Fig. 5e). Spring temperatures reach up to 96 °C, with carbonate deposition rates of approximately 2.5 cm per year. These attributes provide a rare modern analogue for hydrothermal systems associated with early life formation, underscoring the site's exceptional scientific value.

GS7 - Kleopatra Coastal Landforms

Located along the Edremit Gulf, this geosite includes cliffs, tafoni structures, and wetlands developed on Miocene volcanic rocks such as andesite and ignimbrite. The combination of diverse coastal geomorphology and panoramic views toward Lesvos Island enhances the site's aesthetic, educational, and geotourism potential.

GS8 - Kestanbol Ancient Granite Quarry

Located near Troy, the Kestanbol granitoid hosts ancient Roman quarries with partly carved and complete monolithic columns, notably at the Yedi Taşlar site. These remains provide valuable insights into ancient quarrying techniques and illustrate the long-standing interaction between geology and human civilization.

GS9 - Tatlısu Geosite

On the Kapıdağ Peninsula, spheroidal and exfoliation weathering of granitic rocks produces rounded boulders and tor landscapes. These geomorphological features are important for both scientific interpretation and aesthetic appreciation.

GS10 - Tortepe Hill

Tortepe site is located at Kapıdağ peninsula, hosts spectacular granite boulders and tors (Fig. 6c, d). There hundreds of granite boulders scattered over the seafront slopes. Notably, it contains the only known vertical granite outcrop (horn rock) within the Geopark, making it a unique geomorphological feature.

GS11 - Çayağzı Cliffs

Çayağzı cliff profiles at Kapıdağ peninsula are important geological monuments. The cliffs expose outstanding folds and deformation structures within the laminated lithologies. Their accessibility and safety enhance their value for educational and scientific purposes.

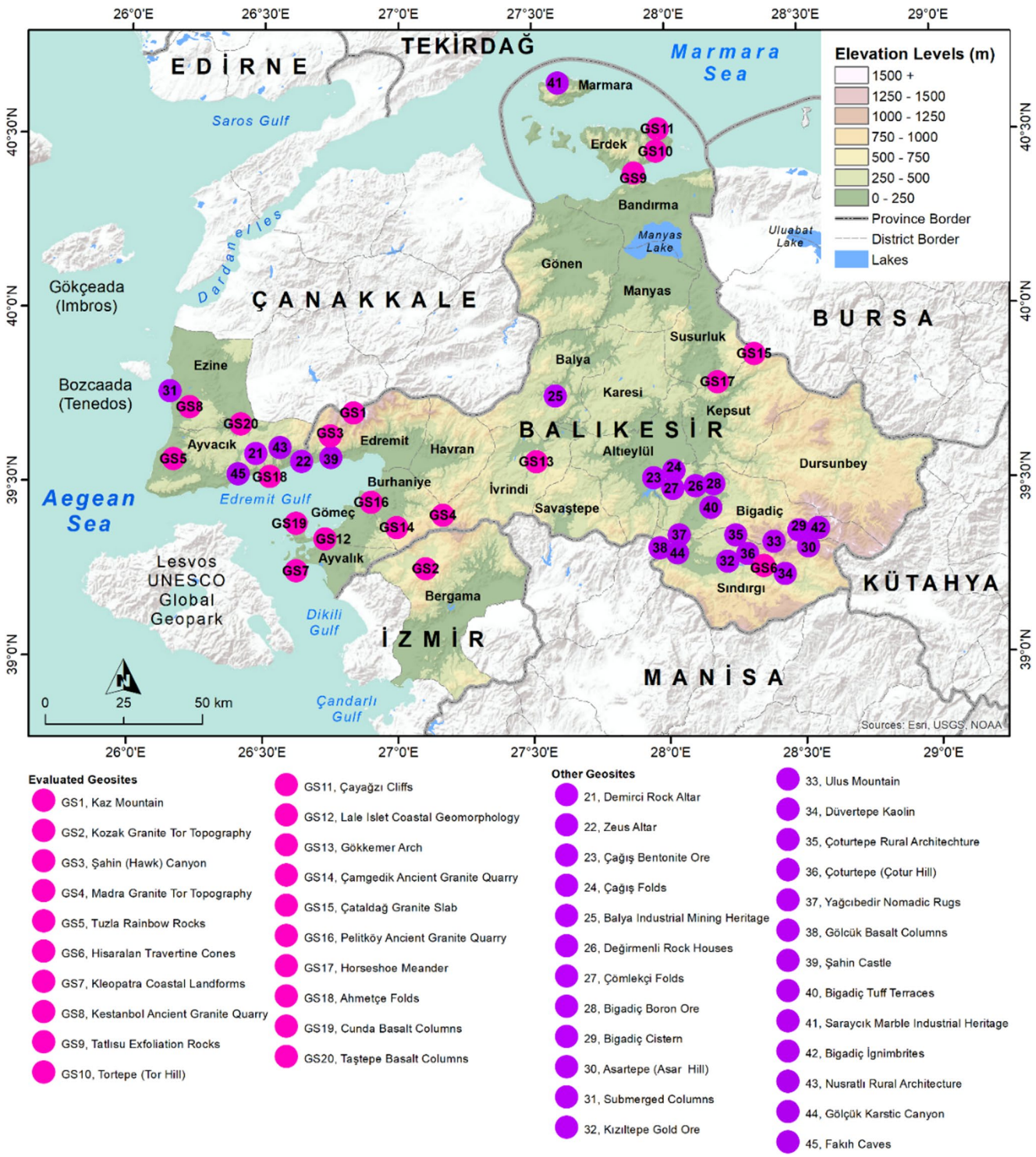

Fig. 4 Geosites of Ida Madra Geopark. Geosites of Ida Madra Geopark. Geosites of the Ida Madra Geopark. Those coded pink were assessed in this study

GS12 - Lale Islet Coastal Geomorphology

The Lale islet is situated near Ayvalık which is connected to mainland with a bridge. This geosite hosts multiple phenomena like sea-diving fault scarps, folds and ancient rock quarries. The advantageous location of the site makes it a very promising geosite for the geopark.

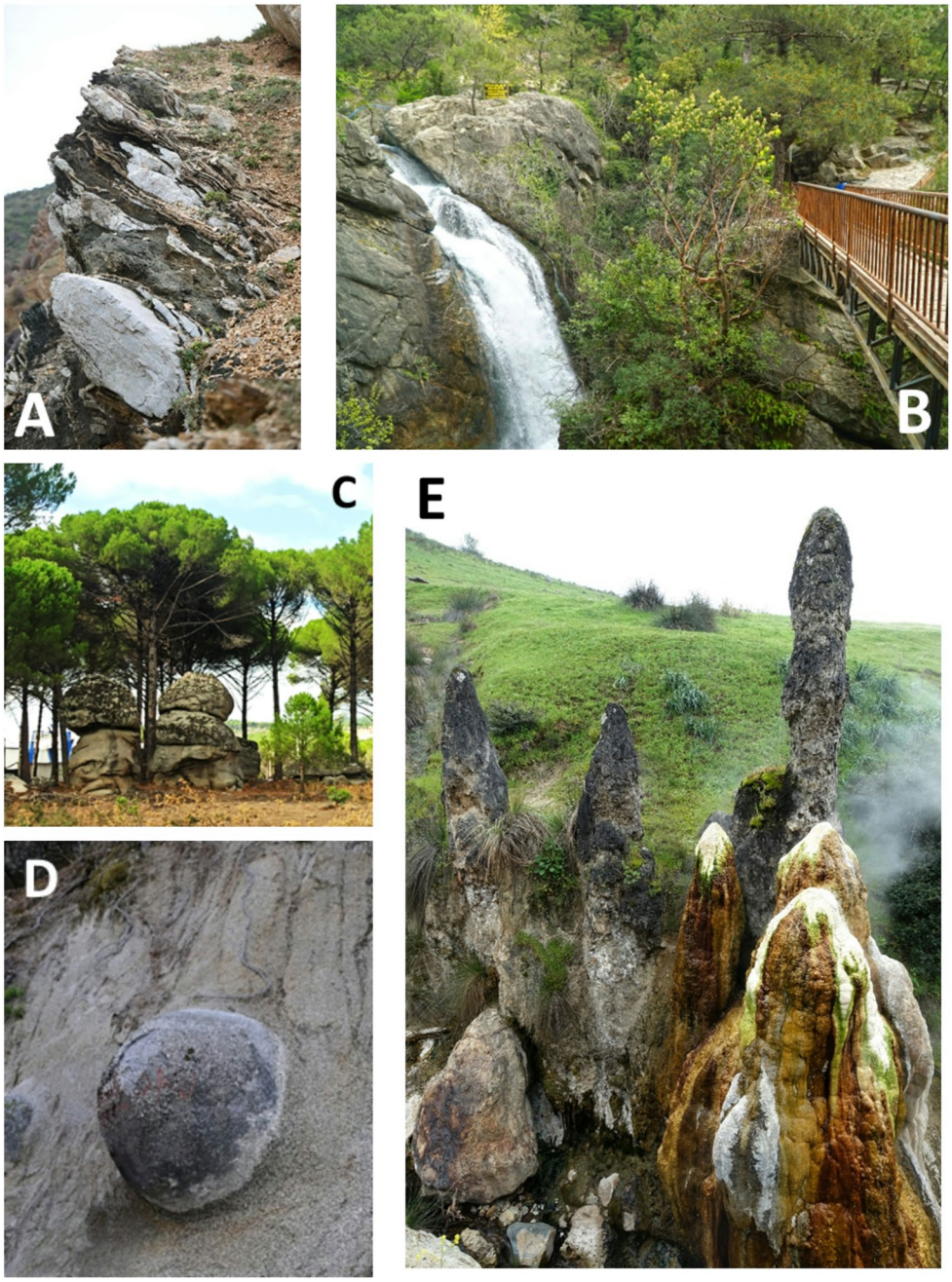

Fig. 5 (a) The high peaks of Kaz Mountain overlooking the Aegean Sea, (b) Sutüven waterfall in Kaz Mountain. A vertical-slip fault plays a role in the formation of this waterfall, (c) Tors and boulders among pine (*Pinus pinea*) trees in Kozak locality, (d) A boulder formed by exfoliation weathering on granodiorite in the Madra Mountain, (e) Hisaralan travertine cones. Hot spring water comes out on the top of column (Photographs by authors).

GS13 - Gökkemer Arch Rock

Gökkemer Arch is a natural limestone bridge formed by the collapse of a cave roof. As an iconic karst feature, it provides valuable information on karstification processes and also serves as a popular site for climbing and outdoor recreation (Fig. 5b).

GS14 - Çamgedik Ancient Granite Quarry

Located northwest of Kuyumcu village in Burhaniye, west of the Geopark, this ancient quarry contains granite columns dating back hundreds of years. The quarried stones were used in the construction of the ancient city of Adramytteion, highlighting the historical use of geological resources in the region.

GS15 - Çataldağ Granite Slab

Situated in Susurluk, the Çataldağ granitoid forms a steep wall-like outcrop measuring 800 m wide and 250 m high. It is significant for understanding the Oligo-Miocene geodynamic evolution of western Anatolia and also serves as a landscape and climbing attraction (Fig. 6b).

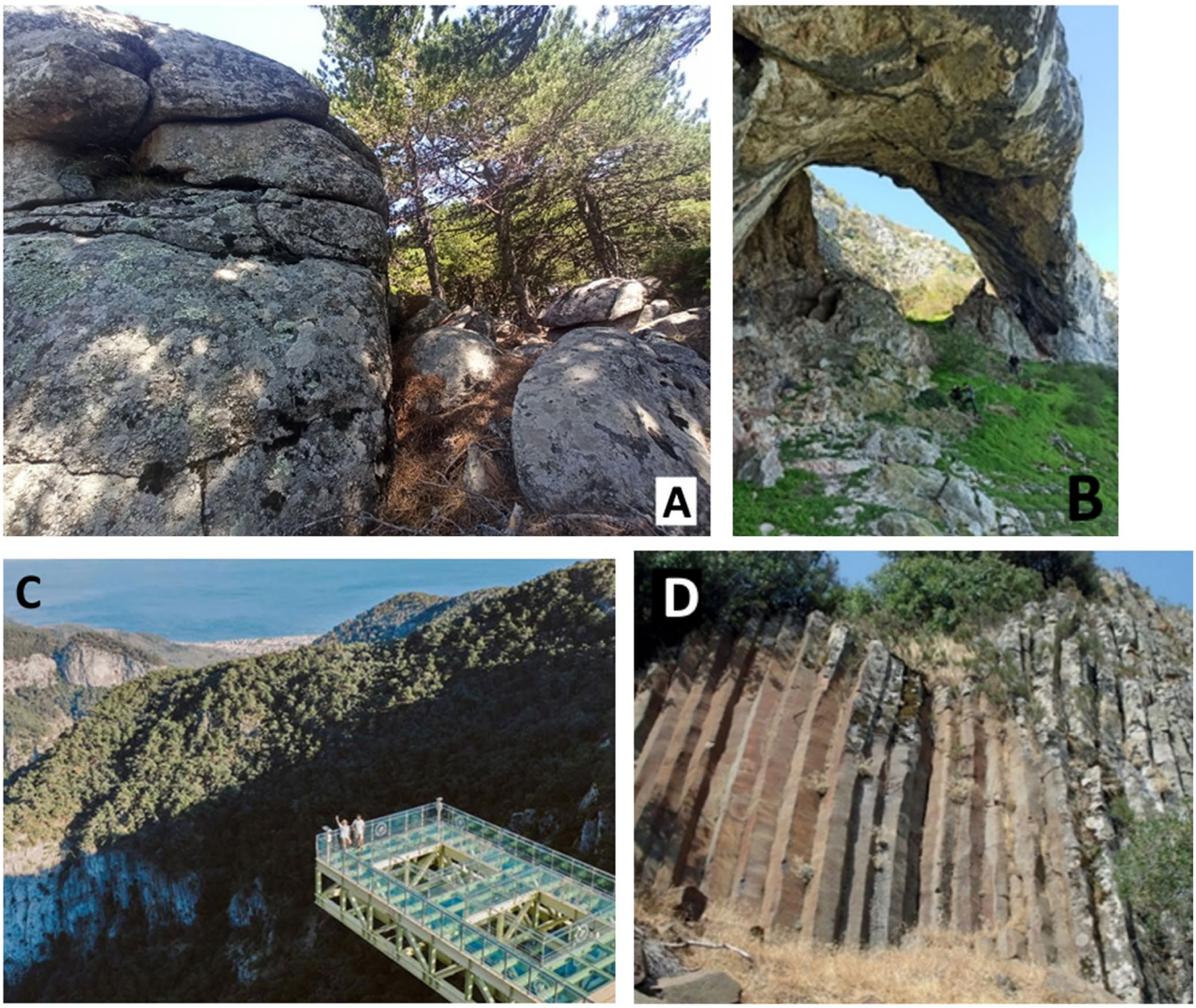

Fig. 6 (a) Tors and boulders in Mt. Madra, (b) Gökkmer Arch Rock, (c) Şahin (Hawk) Canyon viewing platform, (d) Taştepe basalt columns (Photographs by authors)

GS16 – Pelitköy Ancient Quarry

Pelitköy Ancient Quarry is one of the several ancient quarries in the Ida Madra Geopark. The geosite exhibits distinct geological, tectonic, and cultural characteristics. Traces of quarrying indicate that it was used as a quarry in ancient times (Fig. 7).

GS17 – Horseshoe Meander

This iconic meander is located in the middle basin of the Susurluk River, which drains part of the Geopark territory. The perfect symmetry of the embedded meander gives invaluable information of the change in the tectonic regime in the area.

GS18 – Ahmetçe Folds

Located on the southward slopes of the Kaz Mountains near the village of Ahmetçe, this geosite exposes Middle Miocene conglomerates, sandstones, claystones, andesite, trachyandesite, rhyodacite, and Upper Miocene basalts. The folds, clearly visible in road cuts, reflect deformation processes related to regional metamorphism.

GS19 - Cunda Basaltic Columns

Exposed on Cunda Island, these Miocene pseudo basaltic columns display distinctive honeycomb-like jointing formed during cooling and contraction of lava. The site also bears historical significance due to its ancient quarry use and remains a notable geoheritage feature.

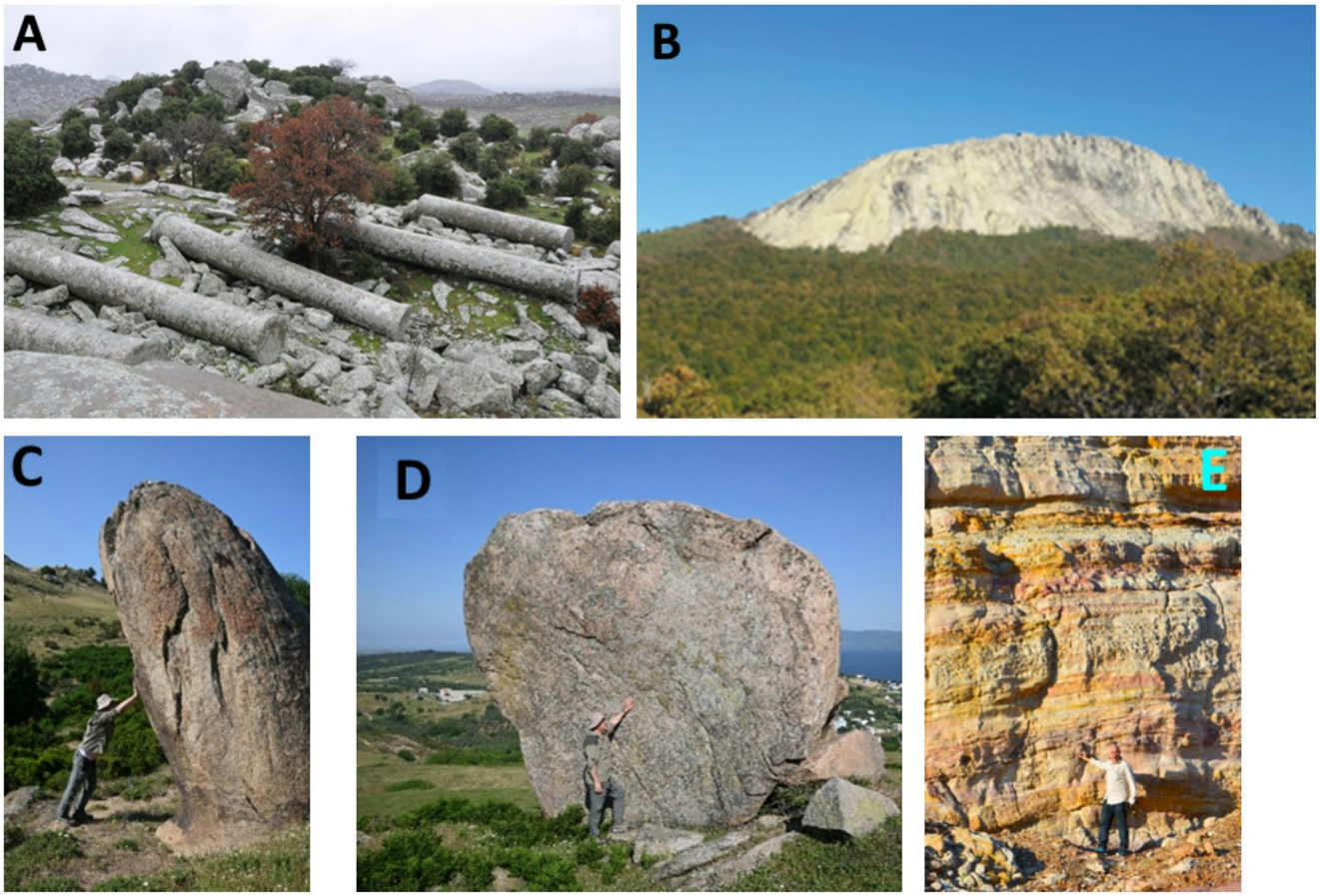

Fig. 7 (a) Granite columns that were quarried and processed hundreds of years ago in Kestanbol, (b) Çataldağ granite slab, (c) Horn rock in Tortepe site, (d) Large boulder in Tortepe, (e) Tuzla rainbow rocks (Photographs by authors).

GS20 - Taştepe Basalt Columns

Located between Karagömlek (Ezine) and Misvak (Ayvacik) villages (Fig. 5d), Taştepe site hosts well-preserved Pliocene aged basalt columns with sharp-edged geometries. Their geological formation and aesthetic qualities make the site particularly valuable for geotourism.

Assessment of the Geosites

The assessment of the geotourism potential of twenty selected geosites within the Ida Madra Geopark produced total scores ranging from 9.00 to 18.25. Among these, Kaz Mountain (GS1) achieved the highest overall score (18.25), whereas the Taştepe Basalt Columns (GS20) received the lowest score (9.00) (Table 2). Thirteen geosites scored above the mean value, while seven fell below it. High-scoring geosites generally demonstrate stronger scientific, aesthetic, educational, and added values, indicating their higher potential as geoheritage assets and their contribution to geotourism development. Many of these geosites could see further improvements by addressing relatively minor deficiencies, whereas low-scoring geosites may require targeted interventions; however, some have inherent limitations that constrain substantial score increases.

To further analyze geotourism potential, total scores were normalized by dividing them by the maximum possible score of 18.50, and the resulting values were classified into four categories: low, medium, high, and very high geotourism value (Table 3). This classification revealed that none of the assessed geosites fall into the low-value category. One geosite was classified as medium value, eight as high value, and eleven as very high value. This distribution highlights the substantial geotourism potential of the Ida Madra Geopark, with the majority of sites providing significant value for both geoheritage conservation and sustainable tourism development. Such distributions are consistent with findings from other geopark-scale assessments, where geological diversity and the integration of cultural heritage enhance overall geotourism performance (Fassoulas et al. 2012; Tomić et al. 2020).

A detailed evaluation across the six assessment categories revealed significant variations:

Table 2 Geosite assessment values of Ida Madra geopark geosites

No.	Geosites	Geotourism Criteria						Total score (max 18.50 points)
		Scientific and intrinsic values (max 4 points)	Educational values (max 4 points)	Economical values (max 3 points)	Conservation values (max 4 points)	Added values (max 2 points)	Aesthetic values (max 1.50 points)	
GS1	Kaz Mountain	4,00	4,00	3,00	4,00	2,00	1,25	18,25
GS2	Kozak Granite Tor Topography	3,50	4,00	3,00	4,00	2,00	1,00	17,50
GS3	Şahin (Hawk) Canyon	3,00	4,00	3,00	4,00	2,00	1,25	17,25
GS4	Madra Granite Tor Topography	3,50	4,00	2,50	3,50	2,00	1,50	17,00
GS5	Tuzla Rainbow Rocks	2,50	4,00	3,00	4,00	1,50	1,50	16,50
GS6	Hisaralan Travertine Cones/Chimneys	3,50	4,00	3,00	2,50	2,00	1,50	16,50
GS7	Kleopatra Coastal Landforms	3,00	4,00	3,00	3,00	1,50	1,50	16,00
GS8	Kestanbol Ancient Granite Quarry	4,00	4,00	2,50	3,00	1,00	1,25	15,75
GS9	Tatlısu Exfoliation Rocks	3,00	4,00	3,00	3,00	1,00	1,00	15,00
GS10	Tortepe Hill	3,00	4,00	3,00	3,00	1,00	1,00	15,00
GS11	Çayağzı Cliffs	3,50	3,50	2,50	3,00	1,00	1,50	15,00
GS12	Lale Islet Coastal Geomorphology	2,00	3,50	3,00	3,00	1,50	1,50	14,50
GS13	Gökkemer Arch	3,50	4,00	2,00	3,00	0,50	1,25	14,25
GS14	Çamgedik Ancient Granite Quarry	2,50	2,50	1,50	3,50	1,00	1,00	12,00
GS15	Çataldağ Granite Slab	3,00	3,50	1,00	3,00	0,50	1,00	12,00
GS16	Pelitköy Ancient Quarry	2,50	2,00	2,00	3,50	1,00	0,75	11,75
GS17	Horseshoe Meander	3,50	3,00	0,50	3,00	0,00	0,75	10,75
GS18	Ahmetçe Folds	2,00	2,00	2,00	3,50	0,00	1,00	10,50
GS19	Cunda Basalt Columns	2,00	2,50	2,50	2,50	0,00	0,75	10,25
GS20	Taştepe Basalt Columns	2,00	2,00	1,50	3,00	0,00	0,50	9,00

Table 3 Definitions of division of geosites into assessment groups

Group	Point value	Definition	Group
I	0–5.00	Geosite with low geotourism value	No geosite
II	5.00–10.00	Geosite with medium geotourism value	1 geosite
III	10.00–15.00	Geosite with high geotourism value	8 geosites
IV	15.00–18.50	Geosite with very high geotourism value	11 geosites

Scientific Value: Scientific scores varied notably among the geosites, reflecting differences in geological diversity, integrity, and representativeness. Kaz Mountain (GS1) and the Kestanbol Ancient Granite Quarry (GS8) achieved the highest scientific scores, owing to their exceptional integrity, rarity, and the coexistence of multiple geological, geomorphological, and cultural features. These geosites serve as key reference points for understanding regional tectonic and geomorphological evolution and encapsulate complex geological histories. In contrast, geosites such as Lale Islet Coastal Geomorphology (GS12), Ahmetçe Folds (GS18), Cunda Basalt Columns (GS19), and Taştepe Basalt Columns (GS20) received comparatively lower scientific scores due to limited geological diversity and fewer observable processes.

Educational Value: Educational value closely paralleled scientific significance but was also influenced by accessibility, clarity of geological features, and the presence of interpretive infrastructure. Eleven geosites attained high educational scores, reflecting their suitability for illustrating Earth history to both specialist and non-specialist audiences. Sites with clear geomorphological expressions and safe access conditions are particularly effective as outdoor classrooms. Conversely, lower educational scores were observed at geosites with restricted accessibility, insufficient signage, or a lack of structured interpretive materials. These findings support previous research indicating that educational value depends not only on geological quality but also on on-site management and visitor facilities (Reynard et al. 2007; Kubalíková 2013).

Economic Value: From an economic perspective, nine geosites achieved maximum or near-maximum scores. These sites benefit from favorable accessibility, proximity to established tourism infrastructure, and the availability of local products such as olives, cheeses, aromatic herbs, and traditional foods. Such factors strengthen connections between geoheritage and local economic development, demonstrating that geotourism in the Ida Madra Geopark has tangible potential to contribute to rural livelihoods. Similar trends have been reported in other geoparks, where integration of local products significantly enhances visitor satisfaction and economic sustainability (Farsani et al. 2014).

Conservation Value: Conservation scores highlight a critical dimension of geosite assessment, particularly for sustainable geopark management. Most geosites achieved above-average conservation scores, especially those within legally protected areas such as national parks, nature reserves, or forest protection zones. Conversely, geosites lacking formal protection frameworks—most notably the Cunda Basalt Columns (GS19) and Hisaralan Travertine Cones (GS6)—received lower scores due to the absence of legal safeguards, institutional oversight, and sufficient financial resources. Despite these limitations, education and training programs incorporated within the geopark master plan offer a positive outlook for enhancing long-term conservation outcomes.

Added Value: Added value, encompassing cultural and ecological associations, was particularly pronounced at Kaz Mountain (GS1), Kozak Granite Topography (GS2), Madra Granite Topography (GS4), and Hisaralan Travertine Cones (GS6). At these geosites, geological features are closely linked with endemic biodiversity, traditional land-use practices, and historical human activities, enhancing both ecological significance and cultural identity. Such integration increases geosite attractiveness and aligns with contemporary interpretations of geotourism as a holistic, place-based experience (Hose 2012).

Aesthetic Value: Aesthetic scores were primarily influenced by geological diversity, structural complexity, and the availability of multiple viewpoints. Sites exhibiting varied landforms, contrasting colors, and expansive visual perspectives—such as granite tor landscapes and coastal geomorphological sites—achieved the highest aesthetic scores. In contrast, geosites that are visually less complex, even if geologically important, received lower aesthetic ratings, highlighting inherent limitations in aesthetic enhancement for certain geological contexts.

Among all evaluated geosites, Kaz Mountain (GS1) displayed exceptional integration across scientific, educational, conservation, and aesthetic dimensions. Granite tor landscapes (GS2 and GS4) and Şahin Canyon (GS3) also ranked highly, further emphasizing the geomorphological diversity of the geopark. Conversely, the Taştepe Basalt Columns (GS20) and Cunda Basalt Columns (GS19) recorded the lowest overall scores, primarily due to limited added and aesthetic values.

Discussion

The predominance of very high-value geosites (55%) indicates that the Ida Madra Geopark possesses a strong foundation for geotourism development. High-value geosites combine scientific diversity, aesthetic appeal, and educational potential, directly supporting visitor engagement, educational activities, and sustainable tourism initiatives. These sites should be prioritized in visitor route planning and infrastructure development to maximize both conservation and economic benefits.

Lower-value geosites, such as the Taştepe (GS20) and Cunda Basalt Columns (GS19), are constrained by limited added and aesthetic values, suggesting their potential for substantial improvement is relatively restricted. However, targeted interventions—such as establishing safe access routes, viewing platforms, and interpretive materials—can enhance visitor experience and educational relevance. Geologically significant but less visually striking sites, such as Ahmetçe Folds and the Horseshoe Meander, hold considerable potential as outdoor classrooms, emphasizing scientific and educational values over aesthetic appeal. Similarly, integrating ancient quarries like Çamgedik and Pelitköy into cultural heritage routes may improve tourism relevance and local engagement.

The integration of geological, ecological, and cultural values enhances geosite attractiveness and visitor satisfaction. Geosites such as Kaz Mountain (GS1) and granite tor landscapes (GS2 and GS4) illustrate how geological diversity can be combined with traditional land use, endemic biodiversity, and historical human activity to produce holistic geotourism experiences (Hose 2012). In addition, the presence of local products and established tourism infrastructure strengthens linkages between geoheritage and local economic development, highlighting geotourism as a tool for rural livelihoods (Farsani et al. 2014).

For sustainable management, it is essential to implement monitoring programs that assess visitor impacts, erosion, and conservation status, particularly in high-value geosites. Active community involvement, thematic route development, and the use of digital tools—including mobile applications, virtual tours, and interactive maps—can further improve accessibility, diversify visitor experiences, and strengthen the distinctive identity of the geopark.

Strategically, prioritizing high-value geosites for visitor routes while enhancing medium- and high-value sites ensures balanced geotourism development. Sites combining strong scientific, educational, and aesthetic values—such as Kaz Mountain, Kozak Granite Topography, Şahin Canyon, and Madra Granite Topography—should be central to route planning. Lower-scoring sites can contribute to geotourism by emphasizing education, conservation awareness, and cultural integration, ensuring that all geosites collectively support the geopark's sustainability, regional development, and UNESCO Global Geopark candidacy.

Conclusions

This study applied the Kubalíková (2013) method to evaluate the geotourism potential of twenty geosites within the Ida Madra Geopark, one of Türkiye's two national geoparks. The results indicate that most assessed geosites fall within the high or very high geotourism value categories, reflecting strong scientific, educational, aesthetic, and conservation attributes. Kaz Mountain, Kozak Granite Tor Topography, Madra Granite Tor Topography, and Şahin Canyon emerged as particularly outstanding sites, combining geological significance with ecological and cultural values. In contrast, lower-scoring sites, such as the Taştepe Basalt Columns, highlight the need for targeted improvements in infrastructure, interpretation, and conservation.

By quantitatively assessing geosite characteristics, this study demonstrates the value of standardized evaluation methods in guiding geopark management and sustainable tourism planning. The integration of conservation priorities, educational initiatives, and economic strategies into geotourism development can enhance the role of the Ida Madra Geopark in supporting local communities and promoting regional development. The findings also emphasize the importance of aligning geosite management with international best practices, ensuring that geoheritage contributes to both scientific understanding and public appreciation.

Overall, the Ida Madra Geopark represents a valuable case study for geotourism in Türkiye, offering insights that are relevant at both national and international scales. Future research should expand the assessment to additional geosites, incorporate visitor perspectives, and explore comparative analyses with other geoparks worldwide. Such efforts will strengthen the role of geosite assessment in achieving sustainable development goals and reinforce the global significance of Türkiye's geoheritage.

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Declarations

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