



HELLENIC REPUBLIC  
**National and Kapodistrian  
University of Athens**

—————EST. 1837—————

FACULTY OF GEOLOGY AND GEOENVIRONMENT

**The importance of Geoenvironmental Education in understanding  
Geological Heritage and promoting Geoethical Awareness:  
Development and Implementation of an innovative assessment  
method, with a case study of the Southeast Aegean islands**

**PhD Thesis**

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Athens, October 2024

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*To my parents,  
from whom I have learned  
more than I have taught*

**Table of Contents**

Table of Figures.....	8
Table of Tables .....	10
Table of Diagrams .....	12
Abstract .....	13
Περίληψη.....	14
Acknowledgements .....	15
Acronyms .....	17
Chapter 1: Introduction and Research Framework.....	19
1.1. Background of the Study .....	19
1.2. Aim and Research Objectives .....	20
1.3. Research Questions.....	21
1.4. Significance of the Study .....	22
1.5. Methodology Overview .....	23
1.5.1. Phase 1: Literature Review and Conceptual Framework Development .....	23
1.5.2 Phase 2: Geological Setting of the Study Area.....	24
1.5.3 Phase 3: Analyzing of Assessment Methodologies for Estimating the Value of Geological Monuments.....	24
1.5.4. Phase 4: Comparative Assessment and Implementation of Geosite Evaluation Methods .....	24
1.5.5. Phase 5: Implementation of GEOAM .....	25
1.5.6. Phase 6: Questionnaire Development, Data Collection, Data Analysis and Interpretation .....	25
1.5.6. Phase 7: Recommendations and Conclusion .....	25
1.6. Structure of the Thesis .....	27
Chapter 2: Conceptual Framework for Geoheritage Promotion .....	29
2.1 Geoheritage and Geoconservation.....	29
2.2. Historical Context and Evolution .....	30
2.3. International Recognition and Initiatives of Geoheritage .....	32
2.4. Sustainable Development and Geoheritage .....	33
2.5. From Environmental Education to Geoeducation .....	36
2.6. Geotourism .....	38
2.7. Geoethics.....	39
Chapter 3: The Geological Heritage of Greece.....	43
3.1. Physiogeography of Greece.....	43

3.2. Geological Setting of Greece .....	44
3.3. The Geological Heritage of Greece .....	46
3.3.1. The UNESCO Global Geoparks of Greece .....	49
3.4. Institutional Framework–Legislation .....	51
3.5. Geotourism development in Greece .....	53
3.6. Geoeducation in Greece .....	56
Chapter 4: Exploring the Geodiversity of Kalymnos, Nisyros, and Samos Islands .....	60
4.1. Introduction .....	60
4.2. Physiogeography of the study area .....	61
4.3. The island of Kalymnos .....	62
4.3.1. Geology-Geomorphology of Kalymnos .....	64
4.3.2. The geological monuments of Kalymnos .....	68
4.4. The island of Nisyros .....	74
4.4.1. Geology-Geomorphology of Nisyros .....	75
4.4.2. The geological monuments of Nisyros .....	79
4.5. The island of Samos .....	83
4.5.1. Geology-Geomorphology of Samos .....	84
4.5.2. The Paleontological Heritage of Samos .....	86
4.5.3. The geological monuments of Samos .....	87
Chapter 5: Assessment Methods for Evaluating Geological Monuments .....	95
5.1. General .....	95
5.1.1 Method of Reynard et al., (2007; 2016) .....	96
5.1.2 Method of Pereira et al., (2007) and Pereira & Pereira, (2010) .....	97
5.1.3 Method of De Wever et al., (2006; 2015) .....	98
5.1.4 Method of Zouros (2007) .....	98
5.1.5 Method of Fassoulas et al., (2012) .....	99
5.1.6 M-GAM Method of Tomić & Božić, (2014) .....	100
5.1.7 The GP method of Brilha (2016) .....	103
5.1.8 Method of Suzuki & Takagi, (2018) .....	105
Chapter 6: On the creation of an innovative Geoeducational Assessment Method - GEOAM .....	107
6.1. Introduction .....	107
6.2. GEOAM as an assessment tool .....	108
6.2.1. Criteria Selection and Definition .....	108
6.2.2. Grading System .....	109
6.3. GEOAM as a promotional tool .....	114

6.3.1. The implementation of GEOAM .....	115
6.3.2 Monitoring and Evaluation of GEOAM Implementation .....	119
6.3.3 Community Involvement: Engaging the Broader Public in GEOAM .....	120
6.3.4 Main Challenges: Addressing Barriers to the Implementation of GEOAM .....	121
Chapter 7: Assessing Geoeducational Potential: Results, Challenges, and Advancements with GEOAM .....	123
7.1. Kalymnos island .....	123
7.1.1. The General-Purpose Model—G-P Method .....	123
7.1.2. The M-GAM Method .....	125
7.1.3 The GEOAM .....	130
7.2. Nisyros island .....	134
7.2.1. The General-Purpose Model—G-P Method .....	134
7.2.2. The M-GAM Method .....	136
7.2.3. GEOAM .....	140
7.3. Samos island .....	143
7.3.1. The General-Purpose Model—G-P Method .....	143
7.3.2. The M-GAM Method .....	146
7.3.3. GEOAM .....	149
7.4 Comparative analysis between the 3 methods .....	153
Chapter 8: Promoting Geoeducation through GEOAM: Methodologies for Engagement and Impact ....	157
8.1. Introduction .....	157
8.1. Training Plan for Implementing GEOAM .....	157
8.1.1. Training Objectives .....	157
8.1.2. Training Components .....	158
8.1.3. Detailed Training Schedule .....	160
Chapter 9: Assessing Geoeducation in Secondary Schools: A Statistical Study of Kalymnos and Nisyros .....	163
9.1. Methodology .....	164
9.2 Application of pre-test (Questionnaire A) .....	164
9.3. GEOAM Training and Post-Test Implementation .....	169
Chapter 10: Future perspectives .....	176
10.1 Discussion .....	176
10.1.1. Research Question 1: What is the current state of geoeducation in the Eastern Aegean islands, specifically in Kalymnos, Nisyros, and Samos? .....	176
10.1.2. Research Question 2: How effective are the existing geoheritage assessment methods (e.g., Brilha’s method and M-GAM) in evaluating the geoeducational potential of geosites? .....	176

10.1.3. Research Question 3: What is the GEOeducational Assessment Method (GEOAM), and how does it differ from traditional geoheritage assessment methods? .....	177
10.1.4. Research Question 4: How do the geosites in Kalymnos, Nisyros, and Samos islands perform when evaluated using GEOAM compared to traditional methods? .....	178
10.1.5. Research Question 5: What are the potential benefits of integrating geoeducation and geotourism in promoting sustainable development on remote islands? .....	178
10.1.6. Research Question 6: What strategies can be developed to enhance the implementation of geoeducation and geotourism in the Eastern Aegean islands? .....	179
10.1.7. Research Question 7: How do the findings of this research contribute to the broader goals of geoheritage conservation and sustainable development as outlined by UNESCO’s Sustainable Development Goals (SDGs)? .....	180
10.1.8. Research Question 8: What is the potential impact of geoeducation on preserving the cultural identity and natural heritage of the Eastern Aegean islands? .....	181
10.2. Challenges and Future Directions.....	182
Chapter 11: Conclusions .....	185
Literature .....	188
Appendices .....	213
Appendix A: GEOAM Assessment Form .....	213
Appendix B: Sample Lesson Plan: Exploring Local Geosites Using GEOAM .....	215
Appendix C: Benchmarks and Success Indicators for GEOAM Implementation .....	217
Appendix D: Questionnaire A (pre-test) .....	219
Appendix E: Exercises of geoeducational program .....	222
Exercise 1 .....	222
Exercise 2 .....	222
Exercise 3 .....	223
Exercise 4 .....	223
Exercise 5 .....	224
Appendix F: Questionnaire B (post-test) .....	225

## Table of Figures

<b>Figure 1.</b> Methodology diagram applied in this study.....	26
<b>Figure 2.</b> Conceptual framework of geodiversity, geological heritage, and geoconservation (Lazzari, 2013, modified).....	30
<b>Figure 3.</b> The logo of the European Geoparks Network (EGN).....	33
<b>Figure 4.</b> The 17 goals for Sustainable Development.....	35
<b>Figure 5.</b> Illustration of the incorporation of the United Nations Sustainable Development Goals (UN SDGs) into a three-tiered nested sustainability model suggested by Rockström & Sukhdev, 2016.....	35
<b>Figure 6.</b> The ABC Approach of Dowling 2013.....	39
<b>Figure 7.</b> Interconnection and components of rational use between geoconservation and geoheritage.....	40
<b>Figure 8.</b> The location of Greece in the southeast Europe.....	43
<b>Figure 9.</b> Sketch map depicting the geodynamic setting of Greece (Angelier & Pichon, 1980, modified).....	45
<b>Figure 10.</b> Schematic reconstruction of the northward dipping Hellenic Subduction system (after Trotet et al., 2001, modified).....	45
<b>Figure 11.</b> Satellite photo of Greece, indicating the location of Geoparks: GP1—Lesvos, GP2—Psiloritis, GP3—Chelmos-Vouraikos, GP4—Vikos-Aoos, GP5—Sitia and GP6—Grevena-Kozani, GP7—Kefalonia-Ithaca, GP8—Lavreotiki, GP9—Meteora Pyli.....	47
<b>Figure 12.</b> Satellite photo of the Dodecanese Island complex, SE Greece; Inlet: Sketch map of Greece indicating the location of Dodecanese island complex.....	63
<b>Figure 13.</b> Satellite map of Kalymnos Island indicating the caves and climbing fields of the study area.....	64
<b>Figure 14.</b> The geology of Kalymnos island according to Franz et al., 2005 (modified by us).....	66
<b>Figure 15.</b> The stratigraphy of Kalymnos according to Mimides et al., 2007 (modified).....	67
<b>Figure 16.</b> (a) Interior of Daskalio cave (GS.K1); (b) the stairs leading to the Daskalio cave (GS.K1); (c) interior of Kefala cave (GS.K2); (d) the entrance of Skalia cave (GS.K4); (e) stalagmites in Skalia Cave (GS.K4); (f) the first staircase to descend to the interior of the Skalia cave (GS.K4); (g) interior of Skalia cave (GS.K4).....	69
<b>Figure 17.</b> (a) The entrance of Stimenia cave (GS.K5); (b) interior of Stimenia cave (GS.K5); (c) a part of the main chamber of the cave Stimenia (GS.K5); (d) at the entrance of the cave-dolini Sikati (GS.K6); (e) in the middle of the Sikati doline (GS.K6); (f) external view of Sikati doline (GS.K6); (g) on the right side of Sikati doline (GS.K6).....	70
<b>Figure 18.</b> (a) Climbing field with the name Archi, in the area of Arginonta (GS.K7); (b) outside of the village Arginonta, the climbers at action; (c) a typical information column for climbers, which lists the exact name of a particular climbing route and the time of its approach; (d) the famous climbing field Grande Grotta (GS.K8); (e) the Grande Grotta climbing field and the wider area.....	71
<b>Figure 19.</b> Location of the Dodecanese complex in the southeastern branch of the South Aegean Active Volcanic Arc, at the convergence limits of the two lithospheric plates, the Eurasian and the African.....	75
<b>Figure 20.</b> Satellite photo of the Dodecanese island complex, SE Greece, indicating the location of Nisyros Island; Inlet: Sketch map of Greece indicating the location of Dodecanese island complex.....	75
<b>Figure 21.</b> Geological map of Nisyros (Papanikolaou et al., 1991), modified.....	76
<b>Figure 22.</b> 3D representation of the surface of Nisyros Island, indicating the location of places referred in the text (Marini & Fiebig, 2005), modified.....	77
<b>Figure 23.</b> Satellite photo of the craters (Vassilopoulou & Hurni, 2001), modified.....	77
<b>Figure 24.</b> Nisyros and the other smaller island around (Lagios et al., 2005), modified.....	79

<b>Figure 25.</b> 3D representation of Nisyros Island, indicating the location of the studied geosites (Marini et al., 1993), modified.....	80
<b>Figure 26.</b> Geosites of Nisyros Island: (a) the Stefanos (GS.N1) and Polyvotis (GS.N2) craters, (b) the Stefanos crater (GS.N1), (c) the Alexandros crater, (d) the Piria hot spring (GS.N4), (e) natural hot spring of Emporios (GS.N3), and (f) Panagia Thermiani thermal spring (GS.N5). .....	82
<b>Figure 27.</b> Geological formations in Greece and Turkey, modified (Mountrakis, 2006) .....	85
<b>Figure 28.</b> Geological map of Samos, modified (Ring et al., 1999) .....	86
<b>Figure 29.</b> Satellite map of Samos indicating key locations on the island and the selected geosites .....	88
<b>Figure 30.</b> Sweeping panoramic view showcasing the Pythagorion area, denoting the geotopes of the tunnel of Eupalinus (GS.S.1) and Panagia Spiliani (GS.S4) with clear markings .....	89
<b>Figure 31.</b> Simplified profile of the Eupalinos tunnel (GS.S1), modified (Seitianidis, 2003) .....	90
<b>Figure 32.</b> The interior sight of the lower point of the ancient quarry (GS.S2) .....	92
<b>Figure 33.</b> The interior sight of the upper point of the ancient quarry (GS.S3) .....	92
<b>Figure 34.</b> The entrance of the Panagia Spiliani cave (GS.S4) .....	94
<b>Figure 35.</b> The interior of the Panagia Spiliani cave (built in the 17th century) with the little church inside .....	94
<b>Figure 36.</b> The GEOAM as a promotion tool for geoeducation .....	115
<b>Figure 37.</b> A simplified flow diagram of the phases of implementing GEOAM in schools .....	116
<b>Figure 38.</b> The key factors of rising GEOAM's implementation .....	116
<b>Figure 39.</b> The development of GEOAM through IT-tools .....	117
<b>Figure 40.</b> The online platform regarding to GEOAM methodology .....	118
<b>Figure 41.</b> The main characteristics of the platform .....	118
<b>Figure 42.</b> The possibility of assessment one geosite through the online platform .....	119
<b>Figure 43.</b> Contribution of GEOAM through geoeducational activities .....	121
<b>Figure 44.</b> Flow chart defining the basic phases of the research .....	164
<b>Figure 45.</b> Pie charts summarizing the awareness of 499 participants (N=499) on various terms and concepts related to geoeducation. Key findings include that 63.3% of participants were aware of the local geological situation, but awareness of other geoscience concepts, such as geological evolution, geosites, geoheritage, and geoeducation, was significantly lower, indicating a general lack of knowledge in these areas. ....	169
<b>Figure 46.</b> Flow chart of the geoeducational program .....	171
<b>Figure 47.</b> Pie charts illustrating the understanding of geoeducation and related terms among the 499 participants (N=499). The majority (44.5%) associate geoeducation with knowledge of geological features, while 26.3% associate it with environmental protection. Responses to geoheritage, geo-conservation, geoethics, geosites, and geoparks indicate a significant awareness of the importance of conservation, ethical management, and education about sites of geological interest. It is worth noting that the results of the post - test showed improved accuracy after the implementation of the geo-educational program. ....	174

## Table of Tables

<b>Table 1.</b> Assessment method of Reynard et al., 2016; Reynard et al., 2007 .....	96
<b>Table 2.</b> Assessment method of Pereira & Pereira (2010); Pereira et al., (2007) .....	97
<b>Table 3.</b> Assessment method of the national geosite inventorying of France, based on De Wever et al., 2006; De Wever et al., 2015.....	98
<b>Table 4.</b> Assessment method of Zouros (2007) .....	99
<b>Table 5.</b> Assessment method of Fassoulas et al., (2012).....	100
<b>Table 6.</b> M-GAM assessment method of Vujičić et al., (2011) and Tomić & Božić, (2014) .....	100
<b>Table 7.</b> Assessment method of Brilha (2016).....	105
<b>Table 8.</b> Assessment method of Suzuki & Takagi, (2018) .....	106
<b>Table 9.</b> Characterization of the final score in GEOAM .....	113
<b>Table 10.</b> Quantitative evaluation of geosites for scientific value (SV) according to G-PM. ....	123
<b>Table 11.</b> Quantitative evaluation of geosites for educational potential use (PEU) according to to G-PM. ....	124
<b>Table 12.</b> Quantitative evaluation of geosites for tourism potential use (PTU) according to G-PM. ....	124
<b>Table 13.</b> Degradation risk evaluation of geosites according to G-PM. ....	125
<b>Table 14.</b> Implementation of M-GAM method in Kalymnos geosites 1 up to 4 (Tomić & Božić, 2014; Božić & Tomić, 2015).....	125
<b>Table 15.</b> Implementation of M-GAM method in Kalymnos geosites 5 up to 8 (Tomić & Božić, 2014; Božić & Tomić, 2015).....	127
<b>Table 16.</b> Results of the application of the M-GAM method in Kalymnos. ....	128
<b>Table 17.</b> Scoring system in the geomorphosites of Kalymnos on SMVE .....	130
<b>Table 18.</b> Scoring system in the geomorphosites of Kalymnos on NRM .....	131
<b>Table 19.</b> Scoring system in the geomorphosites of Kalymnos on EEI.....	131
<b>Table 20.</b> Scoring system in the geomorphosites of Kalymnos on CHS .....	131
<b>Table 21.</b> Scoring system in the geomorphosites of Kalymnos on CIE .....	132
<b>Table 22.</b> Scoring system in the geomorphosites of Kalymnos on GE .....	132
<b>Table 23.</b> Scoring system in the geomorphosites of Kalymnos on EV .....	132
<b>Table 24.</b> Scoring system in the geomorphosites of Kalymnos on SD.....	132
<b>Table 25.</b> Scoring system for the geosites of Kaymnos and the final scores according GEOAM. ....	133
<b>Table 26.</b> Quantitative evaluation of geosites for scientific value (SV) .....	134
<b>Table 27.</b> Quantitative evaluation of geosites for educational potential use (PEU).....	135
<b>Table 28.</b> Quantitative evaluation of geosites for tourism potential use (PTU) .....	135
<b>Table 29.</b> Degradation risk evaluation of geosites .....	136
<b>Table 30.</b> Calculation by M-GAM method of geosites in Nisyros (Tomić & Božić, 2014; Božić & Tomić, 2015).....	137
<b>Table 31.</b> Results of the application of the M-GAM method in Nisyros.....	139
<b>Table 32.</b> Scoring system in the geomorphosites of Nisyros on SMVE .....	140
<b>Table 33.</b> Scoring system in the geomorphosites of Nisyros on NRM.....	141
<b>Table 34.</b> Scoring system in the geomorphosites of Nisyros on EEI .....	141
<b>Table 35.</b> Scoring system in the geomorphosites of Nisyros on CHS.....	141
<b>Table 36.</b> Scoring system in the geomorphosites of Nisyros on CIE .....	142
<b>Table 37.</b> Scoring system in the geomorphosites of Nisyros on GE .....	142
<b>Table 38.</b> Scoring system in the geomorphosites of Nisyros on EV .....	142
<b>Table 39.</b> Scoring system in the geomorphosites of Nisyros on SD .....	142

<b>Table 40.</b> Scoring system for the geosites of Nisyros and the final scores according GEOAM.....	143
<b>Table 41.</b> Quantitative evaluation of geosites for scientific value (SV) according to Brillhas' method....	144
<b>Table 42.</b> Quantitative evaluation of geosites for educational potential use (PEU) according to Brillhas' method.....	144
<b>Table 43.</b> Quantitative evaluation of geosites for tourism potential use (PTU) .....	145
<b>Table 44.</b> Degradation risk evaluation of geosites .....	145
<b>Table 45.</b> Calculation by M-GAM method of geosites in Samos (Tomić & Božić, 2014; Božić & Tomić, 2015).....	146
<b>Table 46.</b> Results of the application of the M-GAM method in Samos.....	148
<b>Table 47.</b> Scoring system in the geomorphosites of Samos on SMVE .....	149
<b>Table 48.</b> Scoring system in the geomorphosites of Samos on NRM .....	150
<b>Table 49.</b> Scoring system in the geomorphosites of Samos on EEI .....	150
<b>Table 50.</b> Scoring system in the geomorphosites of Samos on CHS .....	150
<b>Table 51.</b> Scoring system in the geomorphosites of Samos on GE.....	151
<b>Table 52.</b> Scoring system in the geomorphosites of Samos on EV .....	151
<b>Table 53.</b> Scoring system in the geomorphosites of Samos on CIE.....	151
<b>Table 54.</b> Scoring system in the geomorphosites of Samos on SD .....	152
<b>Table 55.</b> Scoring system for the geosites of Samos and the final scores according GEOAM. ....	152
<b>Table 56.</b> Results after the application of the two methods and after reduction to a common scale.....	155

## Table of Diagrams

<b>Diagram 1.</b> Pie chart regarding of the results of student participation in various school educational programs, based on Georgousis et al., 2021 .....	58
<b>Diagram 2.</b> Pie chart regarding of the most important aspects of geoeducation as reported by 612 pupils and students (Georgousis et al., 2021) .....	58
<b>Diagram 3.</b> The way of the depiction of the results in M-GAM method .....	102
<b>Diagram 4.</b> The display of results from the M-GAM method. ....	130
<b>Diagram 5.</b> The display of results from the M-GAM method. ....	140
<b>Diagram 6.</b> The display of results from the M-GAM method .....	149
<b>Diagram 7.</b> Maximum potential distance from the origin 0 (0,0).....	154

## Abstract

This PhD thesis presents the development and application of the Geoeducational Assessment Method (GEOAM), a novel tool designed to evaluate and enhance the educational potential of geoheritage sites. Recognizing the importance of geoeducation in promoting sustainable development, environmental stewardship, and public awareness of geological heritage, this research addresses a critical gap in existing assessment methodologies by focusing specifically on the educational and ethical values of geosites.

The study begins by assessing the baseline knowledge and perceptions of geological topics among teachers and students through a pre-test. Following a comprehensive geoeducational training program, a post-test with similar questions evaluates the program's impact, revealing significant improvements in understanding basic geological concepts and appreciation of geoheritage. A series of structured questionnaires gathers extensive data on participants' attitudes towards geoeducation, geoheritage, geoconservation, and related topics. Key findings indicate a general agreement on the positive impact of geoeducation on sustainable development, environmental protection, and economic growth. Notably, participants recognize the potential of geoeducational programs to enhance geotourism and improve the standard of living in local communities.

Based on these findings, a Geoeducational Assessment Method (GEOAM) is developed which constitutes an innovative framework to assess and promote geoeducation, geoethical awareness, and sustainable environmental practices. This method is designed to provide a structured approach to evaluating educational programs, teacher training, and curriculum integration, specifically targeting the enhancement of knowledge about geological features, environmental protection, and the responsible use of natural resources.

In the context of the thesis, GEOAM is applied to the case of the Southeast Aegean Islands to assess how geoeducation can be effectively integrated into the educational system, enhancing both the understanding of geological heritage and promoting sustainability and environmental ethics. The method also seeks to explore the potential of geoeducational programs in fostering geotourism and contributing to the economic and environmental development of the area.

**Keywords:** Geoeducation; Geoheritage; Geoethical awareness; GEOAM; Sustainable development; Southeast Aegean Islands

## Περίληψη

Η παρούσα διδακτορική διατριβή παρουσιάζει την ανάπτυξη και την εφαρμογή της γεωεκπαιδευτικής μεθόδου αξιολόγησης (GEOAM), η οποία αποτελεί ένα εργαλείο για την αξιολόγηση και την ενίσχυση του εκπαιδευτικού δυναμικού των περιοχών που εμφανίζουν έντονη γεωκληρονομική αξία. Αναγνωρίζοντας τη σημασία της γεωεκπαίδευσης για την προώθηση της αειφόρου ανάπτυξης, της περιβαλλοντικής διαχείρισης και της ευαισθητοποίησης του κοινού για τη γεωλογική κληρονομιά, αυτή η έρευνα προσδιόρισε ένα αξιοσημείωτο κενό στις υπάρχουσες μεθοδολογίες αξιολόγησης, αναφορικά με την εκπαιδευτική και ηθικά αξία που αντανακλούν περιοχές με ιδιαίτερο γεωλογικό και διεπιστημονικό ενδιαφέρον.

Η μελέτη ξεκινά με την αξιολόγηση της βασικής γνώσης και των αντιλήψεων για γεωλογικά θέματα μεταξύ των εκπαιδευτικών και των μαθητών μέσω μιας προκαταρκτικής εξέτασης. Μετά από ένα ολοκληρωμένο πρόγραμμα γεωεκπαιδευτικής εκπαίδευσης, ένα post-test με παρόμοιες ερωτήσεις αξιολογεί τον αντίκτυπο του προγράμματος, αποκαλύπτοντας σημαντικές βελτιώσεις στην κατανόηση βασικών γεωλογικών εννοιών και στην εκτίμηση της γεωκληρονομικής αξίας. Μια σειρά δομημένων ερωτηματολογίων συγκεντρώνει εκτενή δεδομένα σχετικά με τη στάση των συμμετεχόντων απέναντι στη γεωεκπαίδευση, τη γεωκληρονομιά, τη γεωδιατήρηση και σχετικά θέματα. Τα βασικά ευρήματα δείχνουν μια γενική συμφωνία σχετικά με τον θετικό αντίκτυπο της γεωεκπαίδευσης στη βιώσιμη ανάπτυξη, την προστασία του περιβάλλοντος και την οικονομική ανάπτυξη. Συγκεκριμένα, οι συμμετέχοντες αναγνωρίζουν τις δυνατότητες των γεωεκπαιδευτικών προγραμμάτων για την ενίσχυση του γεωτουρισμού και τη βελτίωση του βιοτικού επιπέδου στις τοπικές κοινωνίες.

Με βάση αυτά τα ευρήματα, αναπτύσσεται μια Μέθοδος Γεωεκπαιδευτικής Αξιολόγησης (GEOAM) που αποτελεί ένα καινοτόμο πλαίσιο για την αξιολόγηση και την προώθηση της γεωεκπαίδευσης, της γεωηθικής ευαισθητοποίησης και των βιώσιμων περιβαλλοντικών πρακτικών. Αυτή η μέθοδος έχει σχεδιαστεί για να παρέχει μια δομημένη προσέγγιση για την αξιολόγηση των εκπαιδευτικών προγραμμάτων, την κατάρτιση εκπαιδευτικών και την ενσωμάτωση των προγραμμάτων σπουδών, στοχεύοντας συγκεκριμένα στη βελτίωση της γνώσης σχετικά με τα γεωλογικά χαρακτηριστικά, την προστασία του περιβάλλοντος και την υπεύθυνη χρήση των φυσικών πόρων.

Στο πλαίσιο της διατριβής, η νέα μεθοδολογία GEOAM εφαρμόζεται στην περίπτωση των νησιών του Νοτιοανατολικού Αιγαίου για να αξιολογήσει πως η γεωεκπαίδευση μπορεί να ενσωματωθεί αποτελεσματικά στο εκπαιδευτικό σύστημα, ενισχύοντας τόσο την κατανόηση της γεωλογικής κληρονομικής αξίας όσο και προάγοντας την αειφορία και την περιβαλλοντική ηθική. Η μέθοδος επιδιώκει επίσης να διερευνήσει τις δυνατότητες των γεωεκπαιδευτικών προγραμμάτων για την προώθηση του γεωτουρισμού και τη συμβολή στην οικονομική και περιβαλλοντική ανάπτυξη της περιοχής.

**Λέξεις-κλειδιά:** Γεωεκπαίδευση, Γεωκληρονομιά, Γεωηθική ενσυναίσθηση, GEOAM, Βιώσιμη ανάπτυξη, Νησιά Νοτιοανατολικού Αιγαίου

## Acknowledgements

First and foremost, I would like to express my deepest gratitude to my supervisor, Prof. Dr. Hara Drinia, for her invaluable guidance, encouragement, and unwavering support throughout this journey. Her expertise, thoughtful insights, and constructive feedback have been instrumental in shaping this work. I also extend my sincere thanks to the members of my committee, Prof. Dr. Assimina Antonarakou and Prof. Dr. Nikolaos Zouros, whose critical input and generous time commitment have greatly contributed to the refinement of this thesis. Their dedication to academic rigor and their belief in my work have been a continuous source of motivation.

I am also deeply appreciative of my colleagues and pupils, whose collaborative spirit and enthusiasm have been an essential part of this research. Their thoughtful discussions, constructive critiques, and diverse perspectives enriched my experience and helped me explore new dimensions of my field. The stimulating intellectual environment we created together has been a driving force behind my progress, and I am incredibly fortunate to have shared this journey with such inspiring individuals.

Finally, I owe an immense debt of gratitude to my family for their constant support, patience, and understanding throughout this long and challenging process. Their unwavering belief in me, even during the most difficult times, provided me with the strength and determination to keep moving forward.

The PhD thesis commenced on December 20th, 2020, under the supervision of Professor Hara Drinia. Throughout the research process and addressing methodological challenges, efforts were made to ensure the thesis's originality and to enhance it through collaboration with other scientists and feedback from reviews. In this context, in-situ field research was conducted, with findings published in various scientific journals and presented at several international refereed conferences. These contributions encompassed the theoretical framework, methodology, and results.

### Journals

1. **Zafeiropoulos, G.**, Drinia, H., Antonarakou, A., & Zouros, N. (2021). From Geoheritage to Geoeducation, Geoethics and Geotourism: A Critical Evaluation of the Greek region. *Geosciences*, 11(9), 381. <https://doi.org/10.3390/geosciences11090381>
2. **Zafeiropoulos, G.**, & Drinia, H. (2021). Kalymnos island, SE Aegean Sea: From fishing sponges and rock climbing to geotourism perspective. *Heritage*, 4(4), 3126-3146. <https://doi.org/10.3390/heritage4040175>
3. **Zafeiropoulos, G.**, & Drinia, H. (2022). Comparative Analysis of Two Assessment Methods for the Geoeducational Values of Geosites: A Case Study from the Volcanic Island of Nisyros, SE Aegean Sea, Greece. *Geosciences*, 12(2), 82. <https://doi.org/10.3390/geosciences12020082>
4. **Zafeiropoulos, G.**, & Drinia, H. (2023). GEOAM: A Holistic Assessment Tool for Unveiling the Geoeducational Potential of Geosites. *Geosciences*, 13(7), 210. <https://doi.org/10.3390/geosciences13070210>
5. **Zafeiropoulos, G.**, & Drinia, H. (2023). Effectiveness of the Geoeducational Assessment Method (GEOAM) in Unveiling Geoeducational Potential: A Case Study of Samos. *Geosciences*, 13(11), 336. <https://doi.org/10.3390/geosciences13110336>

### Refereed Conferences

1. **Zafeiropoulos, G.**, Drinia, H., Antonarakou, A., & Zouros, N. (2022, October). Exploring the wondrous world of a limestone island”: A geoeducational program for the promotion of the geological heritage of Kalymnos Island. In Proceedings of the 16th International Congress of the Geological Society of Greece, Patras, Greece (pp. 17-19).
2. **Zafeiropoulos, G.**, & Drinia, H. (2023, May). A new quantitative assessment method for the geoeducational potential of the geodiversity. In EGU General Assembly Conference Abstracts (pp. EGU-8907). [https://ui.adsabs.harvard.edu/link\\_gateway/2023EGUGA..25.8907Z/doi:10.5194/egusphere-egu23-8907](https://ui.adsabs.harvard.edu/link_gateway/2023EGUGA..25.8907Z/doi:10.5194/egusphere-egu23-8907)

## Acronyms

<b>Acronyms</b>	<b>Explanation</b>
<b>3Gs</b>	Geo-interpretation, Geodiversity, and Geohistory
<b>ABC</b>	Abiotic Biotic Cultural landscapers
<b>AV</b>	Additional Values AV
<b>CHS</b>	Cultural and Historical Significance
<b>CIE</b>	Community Involvement and Engagement
<b>DR</b>	Degradation Risk
<b>EEI</b>	Environmental Education and Interpretation
<b>EGN</b>	European Geoparks Network
<b>ES</b>	Earth Science
<b>ESE</b>	Earth Science Education
<b>EU</b>	European Union
<b>EV</b>	Economic Viability
<b>GE</b>	Geoethics
<b>GEOAM</b>	Geoeducational Assessment Method
<b>GGN</b>	Global Geoparks Network
<b>G-P</b>	Brilha's General-Purpose method
<b>GS</b>	Geomorphosites
<b>GSK</b>	Geomorphosites of Kalymnos
<b>GSN</b>	Geomorphosites of Nisyros
<b>HSS</b>	Hellenic Speleological Society
<b>M-GAM</b>	Modified Geosite Assessment Model
<b>MV</b>	Main Values
<b>NRM</b>	Natural Resource Management
<b>PEU</b>	Educational Potential Use
<b>PTU</b>	Tourism Potential Use
<b>QA</b>	Questionnaire A
<b>QB</b>	Questionnaire B
<b>SD</b>	Sustainable Development
<b>SDGs</b>	Sustainable Development Goals SDGs
<b>SMVE</b>	Site Management and Visitor Experience
<b>SV</b>	Scientific Value
<b>SWOT</b>	Strengths Weaknesses Opportunities Threats
<b>UGGps</b>	Unesco Global Geoparks
<b>UNEP</b>	United Nations Environment Programme
<b>UNESCO</b>	United Nations Educational, Scientific, and Cultural Organization

<b>UNGA</b>	United Nations General Assembly
<b>UNR</b>	United Nations Resolution
<b>VF<sub>n</sub></b>	Functional Values
<b>VPr</b>	Protection Value
<b>VSA</b>	Scenic and Aesthetic Value
<b>VSE</b>	Scientific and Education Value
<b>VTr</b>	Touristic Values

# Chapter 1: Introduction and Research Framework

## 1.1. Background of the Study

Our rapidly urbanizing and interconnected world faces significant environmental challenges, with the global population projected to reach 10.4 billion by 2050, over half of whom will reside in urban areas (**United Nations, 2022**). This urbanization trend impacts land use, biodiversity, and ecosystems, exacerbating issues like pollution, climate change, habitat loss, and resource exploitation (**United Nations, 2019; Gray, 2018**). To address these challenges, informed and active citizens are essential, along with sustainable development policies that integrate economic, social, and environmental considerations (**NAAEE, 2019**).

Geosciences play a pivotal role in understanding and addressing these challenges, with geoconservation emerging as a vital field (**Bohle & Marone, 2021**). Over the past three decades, there has been a global push for "geoconservation" and "geoheritage," reflecting a growing recognition of the importance of preserving Earth's unique geological features (**Reynard & Brilha, 2018; Coratza et al., 2019; Németh et al., 2021; Shekhar et al., 2019**).

The term "geoheritage," which emerged in 1991, underscores the need to safeguard significant geological features such as landforms and geological outcrops. Geoheritage encompasses diverse features critical for understanding Earth's dynamic history, providing scientific insights into past climates and tectonic events, serving as outdoor classrooms for educational purposes, contributing to regional identity culturally, and attracting tourists economically.

The concept of geoconservation traces back to the 19th century, with early efforts in Edinburgh and Germany to legally protect unique rock formations (**McMillan et al., 1999**). Significant milestones include the establishment of Yellowstone National Park in 1872 and global campaigns for land protection in countries like Switzerland and Tanzania (**Schullery, 1999; Brocx & Semeniuk, 2007; Zouros, 2004**).

Geoconservation relies heavily on educating and interpreting information to increase public awareness and participation. Geo-environmental education (geoeducation) is emerging as a crucial field that fosters a deep understanding of the relationship between humans and the environment, contributing to environmentally conscious individuals (**Rakuasa & Latue, 2024**). In the international literature, the term "geoeducation" (**Berrebi, 2006; Sellier, 2009; Cayla et al., 2010; Bollati et al., 2011**) denotes educating individuals about the Earth as a unified entity, aiming to provide insight into the functioning and interaction of natural and human elements within the geographic environment at local, regional, and global levels. Geoeducation encompasses learning activities conducted both within and outside formal educational settings. Within formal education, geoeducation is integrated into various subjects within the conventional national curriculum, while

outside formal settings, it involves guided experiences such as field trips, projects, and visits, occurring in both natural and human-modified environments.

Despite advancements, public awareness of geoheritage and geodiversity remains notably low, highlighting the pressing need for focused geoeducation (**Newsome & Dowling, 2018; Hose, 2012**), particularly in Greece.

The primary goal of this PhD thesis is to investigate and promote the effective implementation of geoeducation in Greece, with a special focus on the islands of Kalymnos, Nisyros, and Samos in the Eastern Aegean. This research explores the conceptual framework of geoeducation, evaluates current conditions and challenges, and develops innovative assessment methods to validate its effectiveness. Furthermore, it examines the role of geoeducation in raising awareness about geoheritage, fostering sustainable development, and enhancing geotourism. The thesis addresses key questions that aim to contribute to the preservation of geoheritage, sustainable development, and the reinforcement of cultural identity within local communities, in alignment with UNESCO's Sustainable Development Goals.

## 1.2. Aim and Research Objectives

The primary aim of this research is to explore and promote effective geoeducation in the Greek region, particularly on the islands of Kalymnos, Nisyros, and Samos in the Eastern Aegean. This involves developing a tool called the GEOeducational Assessment Method (GEOAM) to assess geosites and promote geoeducation through this assessment, ultimately raising awareness, promoting sustainable development, and enhancing geotourism.

One key objective is to study the conceptual framework of geoeducation by exploring its theoretical foundations and practical applications. This includes evaluating the current state of geoeducation, geoheritage awareness, and geotourism, identifying key challenges, and finding opportunities for improvement.

Another important objective is the development and validation of the GEOeducational Assessment Method (GEOAM). This involves critically analyzing existing geomorphosite assessment methods to identify their limitations, creating a novel assessment method focused on geoeducation and societal implementation measures, and testing the effectiveness of GEOAM through its application to selected geosites on the islands.

The research also aims to investigate the potential of geoeducation in raising geo-ethical awareness and promoting sustainable development. This includes assessing how geoeducation can increase awareness of geo-ethical principles, exploring the role of geoeducation and geotourism in promoting sustainable development within local communities, and examining the potential of geotourism to improve living standards and support conservation efforts.

Lastly, the study seeks to contribute to the conservation of geoheritage and the preservation of cultural identity within local communities. This aligns with UNESCO's Sustainable Development Goals (SDGs) specifically Goal 15 (Life on Land), Goal 11 (Sustainable Cities and Communities), Goal 8 (Decent Work and Economic Growth), and Goal 4 (Quality Education) and involves supporting geoheritage conservation through educational and geotourism initiatives, and strengthening cultural identity by highlighting the geological and historical significance of the islands.

### 1.3. Research Questions

The research questions guide the study, focusing on specific aspects that need to be addressed to achieve the research objectives. The main research questions are

1. What is the current state of geoeducation in the Eastern Aegean islands, specifically in Kalymnos, Nisyros, and Samos?
  - a. How is geoeducation currently being implemented in local schools and communities?
  - b. What are the existing challenges and opportunities in promoting geoeducation in these regions?
2. How effective are the existing geomorphosite assessment methods (e.g., Brilha's method and M-GAM) in evaluating the geoeducational potential of geosites?
  - a. What are the strengths and limitations of these methods in the context of geoeducation?
  - b. How do these methods incorporate educational and societal implementation measures?
3. What is the GEOeducational Assessment Method (GEOAM), and how does it differ from traditional geomorphosite assessment methods?
  - a. What criteria and sub-criteria do GEOAM use to evaluate the geoeducational value of geosites?
  - b. How does GEOAM specifically address the educational dimension of geosites?
4. How do the geosites in Kalymnos, Nisyros, and Samos islands perform when evaluated using GEOAM compared to traditional methods?
  - a. What are the key findings from applying GEOAM to these geosites?
  - b. How do these findings compare with the results obtained using Brilha's and M-GAM methods?
5. What are the potential benefits of integrating geoeducation and geotourism in promoting sustainable development on remote islands?
  - a. How can geoeducation raise geo-ethical awareness and promote sustainable practices among locals and tourists?

- b. What role can geotourism play in enhancing the economic and cultural vitality of these islands?
6. What strategies can be developed to enhance the implementation of geoeducation and geotourism in the Eastern Aegean islands?
  - a. How can local communities be effectively involved in geoeducation and geotourism initiatives?
  - b. What specific educational programs, tools, and applications can be implemented to improve the geoeducational value of geosites?
7. How do the findings of this research contribute to the broader goals of geoheritage conservation and sustainable development as outlined by UNESCO's Sustainable Development Goals (SDGs)?
  - a. How can the promotion of geoeducation support SDGs related to quality education, decent work and economic growth, sustainable cities and communities, and life on land?
  - b. What recommendations can be made to policymakers, educators, and local communities based on the research findings?
8. What is the potential impact of geoeducation on preserving the cultural identity and natural heritage of the Eastern Aegean islands?
  - a. How can geoeducation initiatives help in preserving the geological and cultural significance of these islands?
  - b. What are the long-term benefits of promoting a geo-ethical culture among residents and visitors?

By addressing these research questions, the thesis aims to provide a comprehensive analysis and actionable insights into the promotion of geoeducation and geotourism, contributing to sustainable development and conservation efforts in the Greek region.

## 1.4. Significance of the Study

The significance of this study lies in its comprehensive exploration of geoeducation, geoheritage, and geotourism, particularly focusing on the remote and geologically rich islands of Kalymnos, Nisyros, and Samos in the Eastern Aegean. This research has several key contributions that span academic, practical, and policy-making domains.

Firstly, the study enhances the academic understanding of geoeducation by developing a robust conceptual framework and exploring its theoretical foundations. By critically analyzing existing assessment methods and introducing the novel GEOeducational Assessment Method (GEOAM), the research provides a new tool for evaluating the educational value of geosites. GEOAM emphasizes educational dimensions and societal implementation measures, addressing the limitations of traditional methods. The comparative analysis of GEOAM with existing methods

like Brilha's and M-GAM adds depth to the academic discourse, offering insights into the strengths and weaknesses of different approaches.

On a practical level, the research demonstrates how geoeducation and geotourism can be effectively implemented in remote regions. By focusing on the islands of Kalymnos, Nisyros, and Samos, the study provides a model for integrating educational and tourism initiatives to promote sustainable development. The findings highlight the potential of geoeducation to raise geo-ethical awareness, foster environmental empathy, and promote sustainable practices among residents and visitors. This has practical implications for local governments, educators, and tourism operators aiming to develop and implement geoeeducational programs.

Moreover, by developing and validating GEOAM, the study offers a practical tool for assessing geosites and promoting geoeeducation through this assessment. This dual approach not only enhances the academic and practical applications of geoeeducation but also provides a structured method for increasing awareness and appreciation of geological heritage. The research supports the conservation of geoheritage and the preservation of cultural identity within local communities, aligning with UNESCO's Sustainable Development Goals (SDGs). By doing so, it contributes to sustainable development, environmental conservation, and the enhancement of educational and tourism practices in the region.

The study also emphasizes the conservation of geoheritage and the preservation of cultural identity. By highlighting the geological and historical significance of the islands, the research underscores the importance of protecting these unique landscapes. The integration of geoeeducation and geotourism initiatives can help preserve the islands' natural beauty and cultural heritage, promoting a deeper appreciation and understanding among both locals and tourists.

Finally, the study's holistic approach emphasizes the interconnectedness of education, conservation, and sustainable development. By promoting geoeeducation, the research advocates for a broader understanding of environmental issues and ethical considerations. This approach fosters a geo-ethical culture, encouraging responsible behavior and decision-making that supports long-term sustainability.

## 1.5. Methodology Overview

The methodology employed in this study is structured into several distinct phases, each designed to systematically address the research objectives and questions. The phases are outlined as follows (**Figure 1**):

### 1.5.1. Phase 1: Literature Review and Conceptual Framework Development

The initial phase involves a comprehensive literature review to understand the current state of geoeeducation, geoheritage, and geotourism. This includes analyzing existing studies, legislative

frameworks, and key concepts related to geoheritage preservation in Greece. The aim is to highlight the value of geological features in understanding Earth's history and cultural heritage. Based on this, a conceptual framework for geoheritage promotion is developed, laying the groundwork for educational and geotourism initiatives. Additionally, the geological heritage of Greece and the actions taken to promote it are examined.

### 1.5.2 Phase 2: Geological Setting of the Study Area

In this phase, the focus shifts to the geological characteristics of the selected study area, which includes the islands of Kalymnos, Nisyros, and Samos. This involves conducting fieldwork to collect detailed data on the geological characteristics and significance of these islands. Existing surveys and geological maps are used to supplement the field data, ensuring a comprehensive overview. Based on predefined criteria, key geosites are identified and documented. These criteria include the geological significance, educational potential, and tourism appeal of each geosite, providing a robust basis for subsequent phases of the research.

### 1.5.3 Phase 3: Analyzing of Assessment Methodologies for Estimating the Value of Geological Monuments

The third phase of our study focuses on evaluating existing methodologies for assessing geomorphosites, with an emphasis on those that are widely adopted by the global scientific community. This phase involves a detailed examination of the criteria and grading systems used in these methodologies. It has been identified that current methodologies do not adequately address the geo-educational aspects of geosites. To address this gap, we have developed a new methodology that incorporates educational elements into the assessment process. This innovative approach introduces unique criteria, such as the engagement of society, stakeholders, and public administrators, as well as fostering the 4Cs (communication, collaboration, creativity, and critical thinking). In addition, in this phase the pre-test (Questionnaire A) was distributed to ascertain the level of knowledge of the educational community in basic geological topics.

### 1.5.4. Phase 4: Comparative Assessment and Implementation of Geosite Evaluation Methods

This phase focuses on assessing the geological heritage of the three islands of Kalymnos, Nisyros, and Samos using the Brilha, M-GAM, and GEOAM methods. A comparative analysis of these methods is carried out to evaluate their effectiveness in assessing the educational value and societal impact of geosites. By applying each method to the selected geosites, the analysis explores factors such as educational potential, public engagement, ease of use, and overall

comprehensiveness. This comparison identifies the strengths and weaknesses of each method, with a particular emphasis on the distinct advantages of GEOAM in advancing geoeducation.

#### 1.5.5. Phase 5: Implementation of GEOAM

This phase focuses on the practical implementation of GEOAM in schools. It involves selecting pilot schools on the islands of Kalymnos, Nisyros, and Samos and integrating GEOAM into their curriculum. Training sessions for teachers will be conducted to ensure they are equipped to use GEOAM effectively. Educational materials, including lesson plans and interactive activities, will be developed to support the integration. Feedback from teachers and students will be collected through surveys and interviews to assess the effectiveness and practicality of GEOAM in an educational setting. This phase ensures that the method is not only theoretically sound but also practically applicable in real-world school environments.

#### 1.5.6. Phase 6: Questionnaire Development, Data Collection, Data Analysis and Interpretation

The sixth phase, through the post-test (Questionnaire B) aims to assess the state of geoeducation and public awareness of geoheritage among local communities after the implementation of GEOAM in schools. This is achieved by developing and distributing questionnaires targeting students and educators. The questionnaires are designed to gauge awareness, understanding, and attitudes towards geoheritage and geoeducation, allowing for a comparative analysis of changes over time. The data collection process ensures a representative sample, providing critical insights into the effectiveness of the GEOAM method in enhancing geoeducation. Statistical analysis of the questionnaire responses is performed to assess the level of geoeducation awareness and identify areas for improvement, incorporating descriptive statistics to summarize the data and highlight shifts in awareness and understanding.

#### 1.5.6. Phase 7: Recommendations and Conclusion

The final phase develops recommendations and conclusions based on the research findings. Recommendations target policymakers, educators, and local communities to enhance geoeducation, promote sustainable development, and support geotourism. The conclusions summarize key findings, highlight the implications for geoheritage conservation and sustainable development, and propose future research areas. This phase emphasizes the practical applications and potential impact of the study, ensuring its contributions are meaningful and actionable.

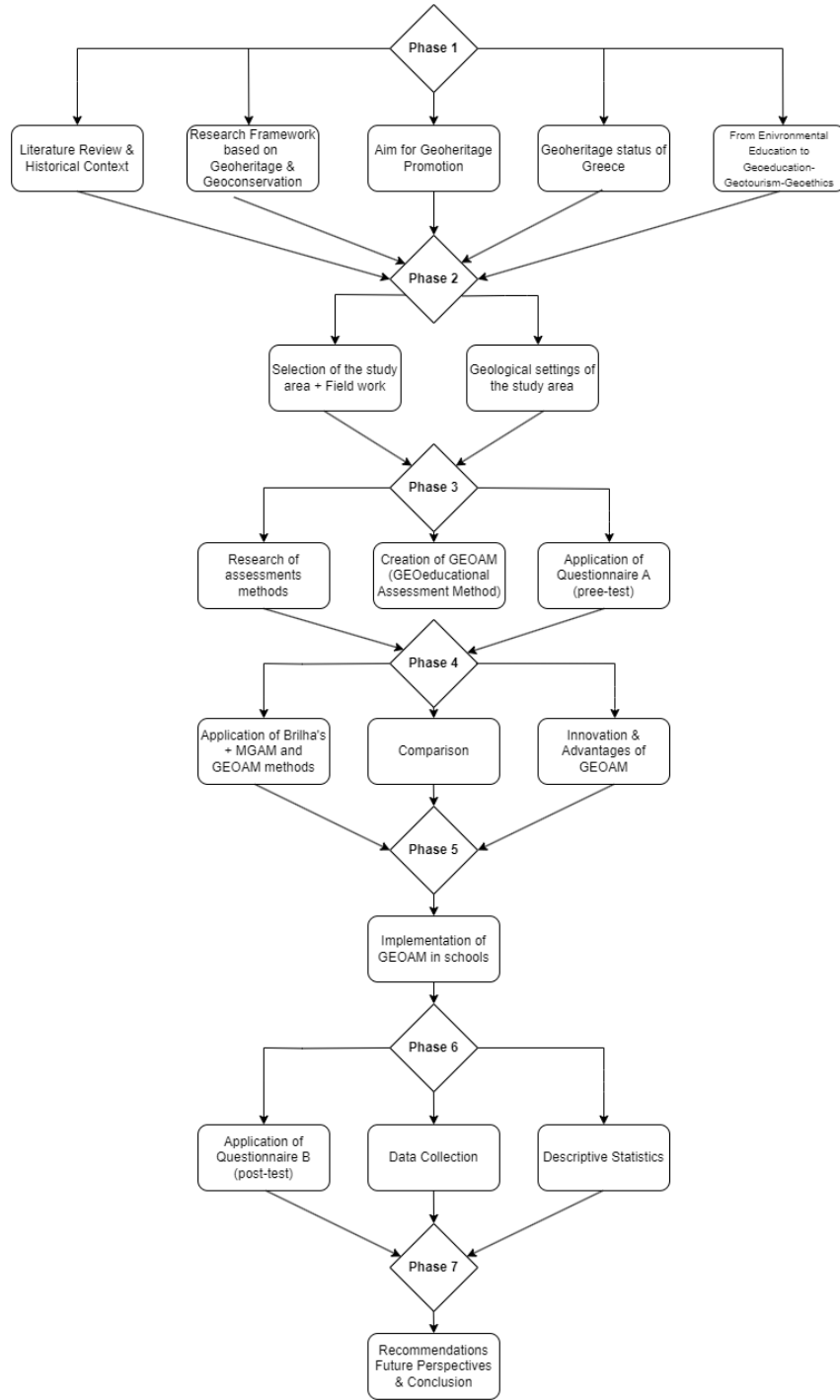


Figure 1. Methodology diagram applied in this study.

## 1.6. Structure of the Thesis

This thesis is structured into eleven chapters, excluding the introduction (the current chapter), each addressing different aspects of the research on geoheritage, geoeducation, and geotourism, particularly focusing on the Eastern Aegean islands of Greece.

**Chapter 2 "Conceptual Framework for Geoheritage Promotion"** delves into the definitions and significance of geoheritage and geoconservation. It explores the intrinsic and extrinsic values of geological features, emphasizing their role in understanding Earth's history and cultural significance. Key concepts related to geoheritage promotion are discussed, establishing a theoretical foundation for the study. The chapter also examines the rationale behind promoting geoheritage and its importance for education and public awareness.

**Chapter 3 "The Geological Heritage of Greece"** provides a historical overview of geoheritage and geoconservation efforts in Greece. It examines the legislative and institutional frameworks that have shaped geoheritage preservation and explores the evolution of geoeducation in enhancing public awareness and involvement in geoconservation. This chapter aims to contextualize the study within the Greek setting, highlighting the country's geological significance and the existing efforts to preserve its geological heritage.

**Chapter 4 "Exploring the Geodiversity of Kalymnos, Nisyros, and Samos Islands"** focuses on the geological setting of the islands of Kalymnos, Nisyros, and Samos. It details their geological characteristics and significance, providing a comprehensive overview of the geological heritage of these islands.

**Chapter 5 "Assessment Methodologies for Evaluating Geological Monuments"**, analyzes various methods, focusing on their structure, criteria, and scoring process for geosites. It also highlights the specific focus of each methodology.

**Chapter 6 "On the creation of an innovative Geoeducational Assessment Method - GEOAM"** introduces the new GEOeducational Assessment Method (GEOAM). It discusses the criteria and rationale for GEOAM, emphasizing its focus on the geoeducational dimension and how it differs from traditional methods by incorporating educational and societal implementation measures. The chapter also describes the development and validation process of GEOAM.

**Chapter 7 "Assessing Geoeducational Potential: Results, Challenges, and Advancements with GEOAM"** details the application of GEOAM alongside other methods (Brilha's and M-GAM) to the selected geomorphosites. It provides a comparative analysis of the results, highlighting the strengths and limitations of each method. The chapter discusses the implications for geoeducation and geoconservation practices, offering insights into how each method can be utilized to promote geoeducation effectively.

**Chapter 8 "Promoting Geoeducation through GEOAM: Methodologies for Engagement and Impact"** focuses on the implementation of the GEOAM method within

educational contexts. It begins with an introduction outlining the importance of using GEOAM to enhance geoeducation. The chapter then presents a detailed training plan for implementing GEOAM, which includes clearly defined training objectives, essential components of the training program, and a comprehensive schedule. This section aims to equip educators with the knowledge and tools needed to effectively use GEOAM for promoting geoeducation and raising awareness of geoheritage.

**Chapter 9 "Assessing Geoeducation in Secondary Schools. A Statistical Study of Kalymnos and Nisyros"** presents a comprehensive analysis of geoeducation within secondary schools on the islands of Kalymnos and Nisyros. This chapter assesses the impact of geoeducation initiatives before and after the introduction of GEOAM, providing valuable data on the effectiveness of the program.

**Chapter 10 "Future Perspectives"** looks ahead to the future of geoeducation, geoheritage, and geotourism. It explores potential advancements in assessment methodologies, the integration of new technologies, and the broader implications for policy and practice. The chapter also discusses the evolving role of geoeducation in fostering sustainable development and enhancing public engagement with geological heritage. Future research directions are suggested, with an emphasis on interdisciplinary approaches and international collaboration.

**Chapter 11 "Conclusions"** summarizes the key findings of the research and discusses their implications for geoeducation, geoconservation, and geotourism in Greece. It provides recommendations for policymakers, educators, and local communities to enhance the promotion and preservation of geoheritage. The chapter concludes with suggestions for future research in the field, emphasizing the study's contributions to UNESCO's Sustainable Development Goals and its potential impact on policy and practice.

## Chapter 2: Conceptual Framework for Geoheritage Promotion

### 2.1 Geoheritage and Geoconservation

The term "geoheritage" refers to the comprehensive appreciation of geological features, with both natural and cultural dimensions. It considers Earth's geological history, geomorphology, and cultural significance, including spiritual, historical, and architectural significance, as well as former mining sites (**Carcavilla et al., 2009**). Geoheritage gives emphasis to the importance of preserving these natural and cultural monuments because of their close connection to human civilization.

According to several researchers (**Semeniuk, 1996; Brocx & Semeniuk, 2007**), geoheritage includes a wide range of geological features, such as igneous, sedimentary, and hydrological aspects. These features have both intrinsic scientific value and extrinsic cultural significance, providing information about Earth's formation, evolution, and scientific history. Geoheritage includes both in situ sites (geological formations preserved in their natural state) and ex situ objects (rocks, fossils, minerals) that are housed in museums and institutions and contribute to Earth science's memory and education.

Geoheritage aims to highlight the diversity of our planet to illustrate the importance of the biotic and abiotic factors that document the historical evolution of the Earth (**Gordon, 2018**). Geoheritage also focuses on the important geological elements such as rocks, minerals and fossils that interpret the effects of past and present actions that have shaped landforms and other geomorphological structures (**McBriar, 1995**). The value of the geological heritage is further underlined in the UNESCO report (**UNESCO, 1999**), which characterizes the geological heritage as a set of the most interesting geological monuments (geotopes, geoparks and geological natural monuments) that deserve to be preserved for scientific, didactic, historical, aesthetic and cultural reasons. There is also a reference in the European Manifesto on Earth Heritage and Geodiversity (**European Manifesto, 2004**), which argues that the Earth's heritage connects the Earth, its people and their culture, i.e. it is the cornerstone and foundation of our society.

Geodiversity plays a pivotal role in the Earth's system and can be defined as the variation in abiotic elements, or the diversity of abiotic features found on the Earth's surface. Together with biodiversity, geodiversity represents the inherent diversity of our planet's natural environment. The link between geological heritage and geodiversity is quite complex and encompasses all elements that contribute to the creation and evolution of the Earth (**Gray, 2004**) (**Figure 2**).

Geoconservation is a relatively new scientific field that has emerged in recent decades due to the growing importance of conservation and sustainable use of environmental resources (**Sharples, 2002**). The field of geoconservation is a relatively recent scientific discipline that has

emerged in recent decades as a response to the increasing significance of conserving and sustainably managing our environmental resources (Sharples, 2002).

The concept of "geoconservation" can be defined as an activity or group of activities that contribute to the conservation, rational management and protection of geological structures that represent geodiversity and thus have scientific and educational value (Brocx & Semeniuk, 2007). The term "geoconservation" first appeared in the 1990s, e.g. (Brocx & Semeniuk, 2007): more specifically, Semeniuk (1996) and Semeniuk & Semeniuk (2001) reported that geoconservation is concerned with the conservation and preservation of the earth's features for educational, scientific and heritage purposes. Etymologically, this term specifically combines conservation with geological features and parameters. The aim of geoconservation is to identify, protect and manage valuable parts of geodiversity. According to international literature, geoconservation is a broad field dealing with issues such as environmental management, geological hazards (geohazards) and sustainable development (Prosser et al., 2011). It is therefore clear that geoconservation is first and foremost a part of geodiversity, together with biodiversity, which together form the two main environmental components. There is also the conservation of geoheritage, which highlights the geological history of the Earth.

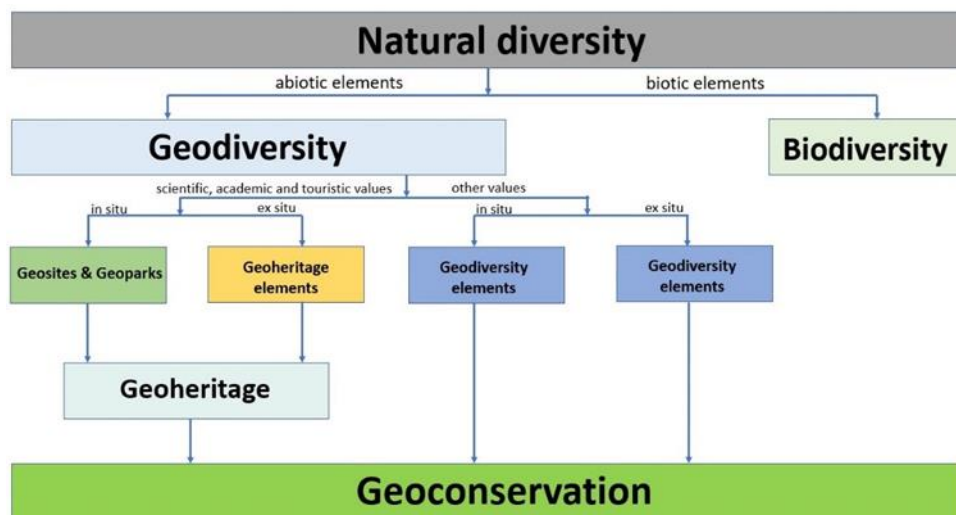


Figure 2. Conceptual framework of geodiversity, geological heritage, and geoconservation (Lazzari, 2013, modified).

## 2.2. Historical Context and Evolution

In the context of the history of science, the concepts of geoheritage and geoconservation, as we understand them today in terms of their scope and objectives, are relatively recent developments, gaining prominence only in the latter part of the 20th century (Gray, 2004). It has

been increasingly acknowledged that the Earth's materials and surface hold the narrative of our planet, and the destruction of this archive, or geoarchive, would result in the loss of crucial data for current and future generations (Gray, 2004). Consequently, there has been a global effort in recent decades to preserve the Earth's heritage, encompassing both intrinsically significant geoheritage sites and culturally significant ones, which embody the history of science (Gray, 2004).

The historical roots of geoheritage and geoconservation initiatives can be traced back to various examples from the 19th century. One notable instance occurred in Edinburgh, Scotland, at the beginning of the 19th century, when over-exploitation in a quarry in the Salisbury area led to significant geomorphological damage to the city. In response, legal measures were enacted in 1819 to protect the characteristic rock formations and prevent further deterioration (McMillan et al., 1999). Similarly, in 1836, Germany established the world's first geological natural monument in the Siebengebirge area near Bonn, following extensive mineral exploitation that had adverse consequences. The Prussian government took the initiative to safeguard the region (McMillan et al., 1999). In the United States, Yellowstone National Park was founded in 1872, primarily for its scenic beauty and diverse geological features (Schullery, 1999). Concurrently, in Switzerland during the 1870s, Fritz Muhlberg initiated a campaign for the protection of erratic stones, which were being systematically exploited. This led to the establishment of a committee in Scotland to propose measures for the preservation of these stones (Jackli, 1979; Gordon, 1994). Notably, Tanzania has emerged as a leader in land conservation efforts, particularly in protecting geological areas like Ngorongoro Lengai, home to an active volcano, as well as diverse fauna and wildlife (Brocx & Semeniuk, 2007). These historical examples highlight early efforts to recognize and preserve the geological heritage of various regions worldwide.

Nowadays in that direction, the International Commission on Geoheritage (IUGS) takes an initiative to record and categorize the geoheritage sites (Page, 2024). According to its official website (<https://iugs-geoheritage.org>), the sites of geoheritage interest are divided to the following nine main sectors:

1. Geomorphology and active geological processes
2. History of geosciences
3. Igneous and metamorphic petrology
4. Impact structures and extraterrestrial rocks
5. Mineralogy
6. Paleontology
7. Stratigraphy and sedimentology
8. Tectonics
9. Volcanology

It is worth noting that a list of 100 regions already exists, with another list of 100 locations to be released soon. Among these, two sites in Greece have been included: the petrified forest of Lesvos and Santorini's volcanic caldera.

Moreover, there are some locations with a strong cultural and geoheritage value at the same time. A typical example is the Sugar Loaf Monolith of Rio de Janeiro (Brazil). This site contains huge potential mainly due to the special location and the unique landscape. Consequently, there is also a huge tourist capability within this area with urban positive dimensions. For this reason, the study of geoheritage within urban settings is a commonly explored topic at the intersection of geoheritage and cultural heritage. This field closely aligns with urban geomorphology, which explores how landform patterns impact the development and expansion of towns and cities.

Furthermore, **Gordon (2018)** recently conducted a thorough review of the connection between geoheritage and cultural landscapes, exploring their significance and various interrelations. In other terms, cultural landscapes are linked to agricultural activities such as vineyards or salt pans.

On the other hand, there are still areas with a huge tourist influx every year and have not yet been recognized as areas of global geoheritage value. One such example is Petra in Jordan with its arid zone sandstone geomorphology, slot canyons, weathering features.

However, it should be emphasized that technology can contribute positively to the preservation and promotion of geoheritage value. Since geoheritage value has multidimensional impacts on the urban environment and local economic development. Conserving geoheritage is essential and beneficial for modern societies due to its correlation with cultural variety, societal cohesion, identity, adaptability, and the economic well-being of local communities.

Additionally natural phenomena, including climate changes or fluctuations, especially extreme events, frequently disrupt geoheritage, leading to its deterioration or destruction. For example, the remains of a medieval church in Trzęsacz, located in northern Poland, were destroyed because of the erosion of the sea cliffs. Moreover, because of climate change are observed flood marks, that are intensive and can be disastrous for geoheritage sites (**Pijet-Migoń & Migoń, 2022**).

For the aforementioned reasons, the promotion and evolution of geoheritage shows its importance. Because it can raise awareness and more ethical behaviors regarding the management and protection of the environment.

### 2.3. International Recognition and Initiatives of Geoheritage

The global recognition of geoheritage and its preservation is endorsed by two United Nations initiatives—the Convention concerning the Protection of the World Cultural and Natural Heritage and the International Geoscience and Geoparks Programme. Established in 1972, the Convention allows countries worldwide to propose cultural and natural sites to UNESCO (United

Nations Educational, Scientific and Cultural Organization) for recognition as having Outstanding Universal Value (OUV). One of the assessment criteria, criterion (viii), is concerned with the scientific significance of geoheritage, emphasizing its representation of major stages in Earth's history as well as ongoing geological processes. Additionally, criterion (vii) takes into account the aesthetic value of natural features. Criterion (viii) was used to justify the OUV of geoheritage for 93 sites in 51 countries, accounting for 44% of all natural properties on the World Heritage List in July 2019. Australia leads with 12 listed properties, followed by the United States, Canada, China, and Italy.

The International Geoscience and Geoparks Programme, UNESCO's second geoheritage initiative, was adopted in 2015. This program defines UNESCO Global Geoparks as areas of geological heritage with international significance, emphasizing a bottom-up approach to heritage conservation, community engagement, and sustainable development. The geopark concept originated in Europe in the 1990s and gained UNESCO support following its success. Geoparks are expected to actively promote economic development in their respective areas by raising geological heritage awareness and encouraging geotourism growth. Geoparks should collaborate with local businesses to create new geological heritage products. The primary goal of all Geoparks is to raise awareness, protect, preserve, and promote the geological and geomorphological elements on their respective lands. The European Geoparks Network (**Figure 3**), founded in 2000, was the first international platform for geoparks to facilitate exchange and cooperation.



**Figure 3.** The logo of the European Geoparks Network (EGN)

## 2.4. Sustainable Development and Geoheritage

The United Nations adopted the Sustainable Development Goals (SDGs) in 2015 as a comprehensive framework for global development, covering crucial challenges such as poverty reduction, environmental conservation, and social fairness. The 17 Sustainable Development Goals (SDGs) outlined in the UN's 2030 Agenda were overwhelmingly agreed by all 193 member states at the 21st Conference of Parties (COP21) in Paris in December 2015. These goals, together known as the Paris Agreement, provide an important framework for addressing climate-related

issues. It is worth noting that all 17 SDGs are intertwined with Earth science (ES), emphasizing the critical role of the geological scientific community in accomplishing these objectives.

Within the SDGs, UNESCO defines eight specific goals that are especially relevant to UNESCO Global Geoparks (UGGps) (UNESCO, 2015). These goals include SDG 1 (No Poverty), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals). They highlight the importance of geological heritage in encouraging sustainable development. One of the initiatives mentioned in the United Nations' 2030 Agenda is to promote education for sustainability (EfS), which aims to improve understanding of sustainability principles and encourage prosperity while respecting the earth and its inhabitants. Earth science (ES) education is critical to EfS, and widespread distribution of ES concepts is required to improve society's understanding of sustainability challenges.

Geosciences, which includes disciplines such as geoconservation, play an important role in furthering the SDGs by protecting critical geological monuments and advocating for their sustainable management (Gordon et al., 2018; Stephens, 2020). Geoconservation strategies facilitate the integration of biological and geological diversity conservation, thereby contributing to several SDGs, including SDG 15 (Life on Land) and SDG 14 (Life Below Water) (Gordon et al., 2018; Stephens, 2020). Brilha (2018) emphasizes the direct relevance of geoconservation to multiple SDGs, stressing the need for collaborative efforts to develop comprehensive conservation strategies.

In addition, geological heritage, by means of geotourism efforts, contributes significantly to the advancement of SDG initiatives. Geotourism, which focuses on geological attractions, encourages sustainable tourism practices, stimulates local economic growth, and strengthens community resilience (Gill, 2017). Geotourism helps to achieve broader sustainable development goals by aligning with SDGs such as sustainable tourism, economic growth, and environmental preservation (Gill, 2017).

As a result, the relationship between geoheritage and sustainable development illustrates the significance of integrating geological knowledge and conservation initiatives to address global concerns integrally. Geoconservation and geotourism programs help to advance the overarching goals of sustainable development by concentrating on specific SDGs such as poverty reduction, education, gender equality, sustainable cities, climate action and partnerships (Figures 4 and 5).



Figure 4. The 17 goals for Sustainable Development

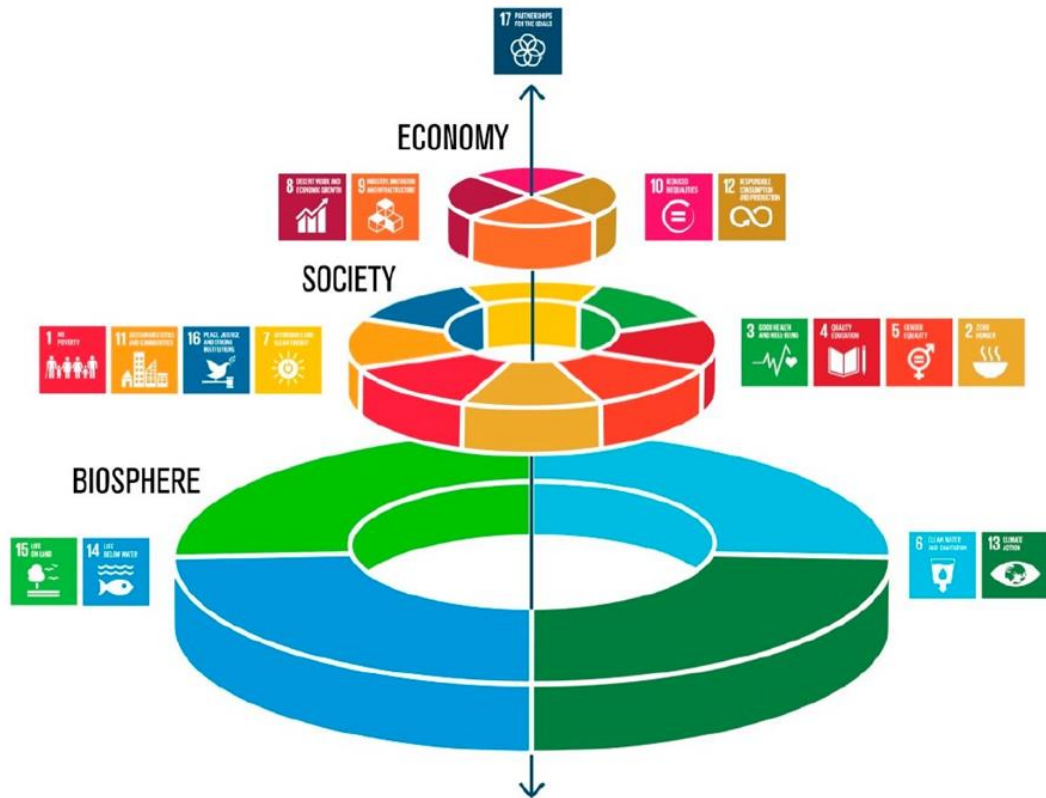


Figure 5. Illustration of the incorporation of the United Nations Sustainable Development Goals (UN SDGs) into a three-tiered nested sustainability model suggested by Rockström & Sukhdev, 2016

## 2.5. From Environmental Education to Geoeducation

As the world's population grows and urbanization accelerates, the burden on natural resources and ecosystems increases, worsening problems like pollution, habitat loss, and climate change. This growing environmental deterioration highlights the critical need for comprehensive educational initiatives that promote ecological literacy, sustainable habits, and a greater knowledge of humanity's interconnectedness with the natural world. In response to these pressing issues, environmental education has developed as a catalyst for increasing knowledge, encouraging action, and instilling a sense of environmental responsibility in individuals and communities all over the world. Environmental education has emerged as an important response to the world's growing environmental challenges in the current century. Environmental education aims to equip individuals to become informed advocates for environmental protection and sustainable development by using new pedagogical approaches, interdisciplinary collaborations, and community participation.

Environmental education (EE) has been a global endeavor for over six decades, evolving through various terms and frameworks reflecting changing priorities and objectives (**Stapp, 1969; UNESCO-UNEP, 1977; UNESCO-UNEP, 1978; Huckle, 1991; Tilbury, 1995; UNESCO, 2017; UN, 2005**). UNESCO initiatives have significantly advanced environmental education, with pivotal moments such as the Charter of Statutes of Belgrade emphasizing the necessity for comprehensive environmental education to tackle global environmental challenges (**UNESCO-UN, 1975**). Environmental Education aims to produce a citizenry that is aware of the biophysical environment and the problems associated with it and motivated to work toward their solution. On the other hand, Education for Sustainable Development (ESD) is a lifelong learning process and an integral part of quality education that enhances the cognitive, social and emotional, and behavioral dimensions of learning. It is holistic and transformational and encompasses learning content and outcomes, pedagogy, and the learning environment itself (**UNESCO, 2005**).

Nevertheless, most environmental education programs do not clearly incorporate geoethics, geodiversity, or geoheritage. Geoeducation, which focuses on providing knowledge about significant geological locations is vital for narrowing this gap and promoting geotourism services (**Trikolas & Ladas, 2013**).

Geoenvironmental education, an aspect of environmental education, addresses social concerns about the environment and its complex interactions with human activity. It incorporates the principles and concepts required for imparting geological knowledge, as well as both natural and human-induced geological events (**Rokka, 2018; Peppoloni & Capua, 2016**). This educational approach takes into account not only biotic and abiotic variables, but also cultural dimensions, making it an important tool for underlining the value of geological heritage and geoconservation (**Zafeiropoulos et al., 2021**). Furthermore, geoenvironmental education promotes environmental responsibility by imposing a geoethical code (**Peppoloni & Di Capua, 2022; Georgousis et al., 2022**). Integrating geoeducation into school curricula at all levels is

critical for raising awareness of geological heritage (**McKeever & Zouros, 2005**). UNESCO identifies education and sustainable development as essential objectives for World Geoparks, highlighting the significance of improving student understanding of sustainability (**UNESCO, 2005**).

According to **Orion (2019)**, Geoeducation or Geoscience Education (GE) or Earth Science Education (ESE) provides students with the cognitive skills needed to develop environmental insight: the ability to overcome cognitive barriers to spatial and temporal thinking, retrospective and understanding of phenomena on scales of many orders of magnitude, integration of different topics, and development of cognitive capacity for systematic thinking.

Geoeducation combines natural, cultural, and local geology in both formal and informal educational environments (**Fernández Álvarez, 2020**). It is critical in communicating information about geological monuments, the planet's historical evolution, and the ethical implications of significant geological locations. Geotopes and geoparks are great resources for in situ geoeducation, promoting a better understanding of geological processes and responsibility for the environment. Natural history museums in geoparks make substantial contributions to learning opportunities and research support (**McKeever & Zouros, 2005**).

One of the objectives mentioned in the United Nations' 2030 Agenda is the promotion of education for sustainability (Efs), which aims to improve understanding of sustainability principles and encourage prosperity while respecting the earth and its inhabitants. Earth science (ES) education is critical to Efs, and extensive dissemination of ES concepts is required to improve society understanding of sustainability challenges.

Unfortunately, sustainability education and research have repeatedly ignored geological sciences and showed a lack of awareness of the Earth's history and dynamic systems. This gap puts at risk efficient mitigation initiatives under the sustainability umbrella, potentially compromising our ability to protect humanity's future.

The traditional education system commonly ignores the significance and elements that comprise geological heritage, stressing the need to extend geoeducation availability and integrate it into specialized curriculum programs at all educational levels. This provides a valuable opportunity for future generations to learn about geological and cultural topics. Notably, the European and Global Geopark networks play critical roles in promoting comprehensive geoeducation by offering on-site possibilities for the public and scientific community to participate in educational and cultural events (**Mc Keever & Zouros, 2005; EGN, 2005**). UNESCO Global Geoparks are excellent opportunities to assist schools as outdoor classrooms and to be incubators of sustainable development, sustainable lifestyles, the appreciation of natural and cultural diversity and the promotion of peace. For these reasons, UGGps are also effective strategies for the promotion of the seventeen United Nations Sustainable Development Goals. Geoparks' geosites and geotrails provide useful tools for skilled geoguides to educate visitors about their significance and ecological impact.

UNESCO's strategy and planning stress education and sustainable development as the key goals of Global Geoparks. Meaningful dissemination of information and geoeducation about sustainable development inside geoparks can serve a variety of purposes, with an emphasis on both geological and cultural heritage. Thus, the immediate goal of a geopark is to help visiting students better understand sustainability, with the ultimate objective of improving living conditions for generations to come.

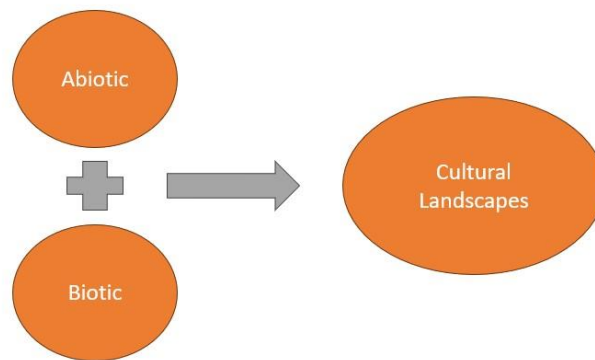
## 2.6. Geotourism

Geotourism is an emerging and dynamic phenomenon, with multiple approaches affected by specific geological features. As a result, there is no common definition of geotourism. It can be viewed as a combination of tourism and geology, with tourism emphasizing subjective and aesthetic characteristics and geology relying on objective standards. Geotourism develops as an environmentally creative kind of tourism that combines these two unique fields.

This type of alternative tourism has a high growth potential, particularly with the creation of geoparks in the early twenty-first century. Geoparks, or designated areas known for their geological heritage and natural/cultural surroundings, are important in fostering responsible tourism and sustainable development (**Herrera-Franco et al., 2020**).

Multiple meanings of geotourism have been proposed, but it is primarily a subset of ecotourism that occurs in areas with important geological monuments (**Robinson, 2008; Farsani et al., 2013**). Geotourism focuses on interactive experiences with geological and cultural components, emphasizing each location's distinct uniqueness. It focuses on environmental features such as landscape and geoenvironment, as well as cultural and natural heritage that are inextricably related to the geological environment (**Joyce, 2006; Kanellopoulou, 2015**).

Understanding the unique characteristics of a location is critical for promoting geotourism. **Dowling (2013)** developed the "ABC" framework (**Figure 6**), which includes abiotic (geology, climate), biotic (fauna, flora), and cultural aspects as essential. Geotourism declares recognizing the environment's complexity involves familiarity with abiotic influences, that affect biotic components and cultural features across time (**Dowling, 2013**).



**Figure 6.** The ABC Approach of Dowling 2013

To summarize, geotourism can help promote local sustainable development, but it must conform to standards that prioritize environmental and geoheritage preservation. As a result, a comprehensive approach is taken, providing that geotourism activities have distinct characteristics. Integrated management is required to accommodate visitors while also protecting geological, ecological, social, and cultural resources. Responsible resource management should reduce waste, and geotourism projects should generate chances for local development that are environmentally friendly and reflect the area's unique character, increasing the local economy.

Geotourism products and services should promote teaching, especially among young people and students, by utilizing modern technological tools to enhance awareness of geology and the environment. Recreational activities should use technology applications and planned itineraries to increase engagement. Initiatives promoting geotourism reinforce respect for local traditions, emphasize authentic values, and raise awareness about geodiversity and environmental conservation among visitors (**Inskeep, 1991**).

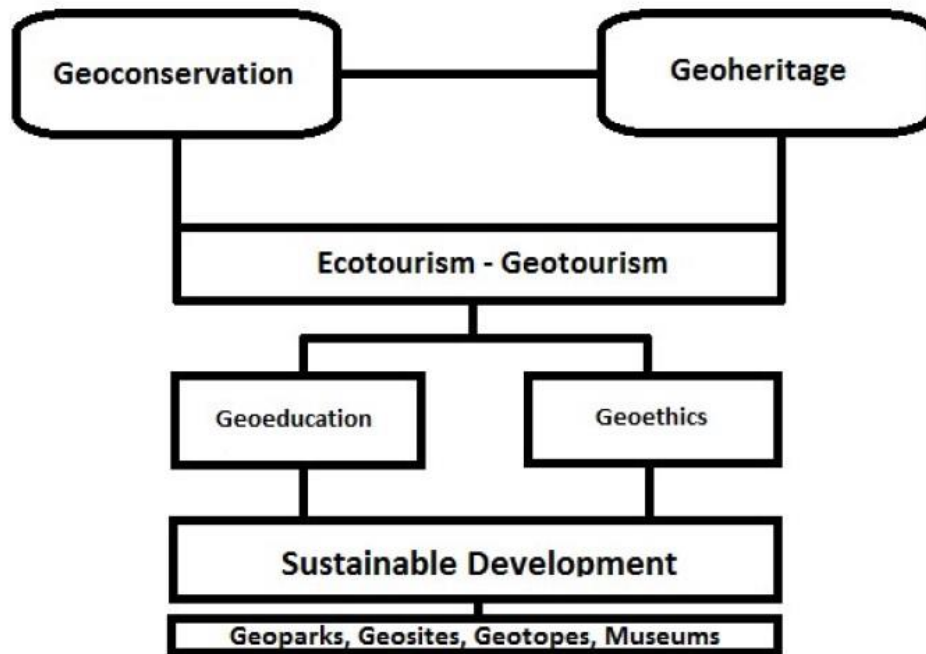
## 2.7. Geoethics

Geoethics is an increasingly prominent field which examines how geoscientists interact with society and the environment. It investigates the ethical, social, and cultural aspects of geoscience research and practice, often collaborating with subjects such as sociology and philosophy. This field offers geologists the opportunity to recognize their societal roles and responsibilities in the course of their work. As per **Peppoloni et al., (2015)**, "Geological culture and geoethics can strengthen the connections between individuals and their landscapes, between their places of origin and their personal memories," by acknowledging the significance of a region's geological heritage. Education is also important in communicating to the community the environmental concerns and the sustainable use of natural resources, as well as the consequences of damaging geological heritage (**Brocx & Semeniuk, 2019**). As a result, geoethics can help raise public understanding about geopolitics resources and the geoenvironment. An ethical approach should underscore the value of nature as a sensory, contemplative, spiritual, religious, and aesthetic

experience that is passed on to future generations, moving beyond mere consideration of the economic viability of natural resources (Chan et al., 2016; Slaymaker et al., 2015; Winter, 2007).

The concept that nature has inherent value and deserves to be protected is typically based on spiritual or metaphysical beliefs. However, it also arises from human ethical issues and obligations toward the natural environment, with the protection of biodiversity and cultural heritage (Papayannis & Howard, 2007; Vucetich et al., 2015; Drinia et al., 2021).

Within the growing domain of geoethics, geotourism assumes a cultural function. According to Peppoloni and Di Capua (2015), geoethics strengthens geoeducation by promoting tourism and UNESCO Global Geoparks, with the goal of raising awareness, instilling values, and cultivating a feeling of responsibility for geological heritage, particularly among younger generations. As a result, it is clear that this new scientific discipline acts as a prelude to achieving greater sustainability in all of its dimensions, namely the environment, economy, and society. Consequently, driven by the imperative resulting from the extensive and systematic utilization of our planet, this novel field places a strong emphasis on the requirement for a more specialized understanding of sustainability (Vascanelos et al., 2015). Its ultimate objective is to facilitate the dissemination of knowledge from academia to society, as shown in Figure 7.



**Figure 7.** Interconnection and components of rational use between geoconservation and geoheritage

Geoethics primarily addresses the most urgent and significant environmental concerns, including issues like the greenhouse effect, climate change, pollution, and challenges related to waste management. Its overarching objectives include fostering critical thinking about the

utilization of Earth's natural resources, the development of environmentally sustainable technologies, and the dissemination of knowledge concerning natural hazards (**Peppoloni & Di Capua, 2015**). The integration of geoethics into geotourism endeavors can heighten awareness of sustainability, encouraging local communities to adopt responsible resource management practices. Therefore, it is well-understood that in every facet of human society, there must be a commitment to uphold the principles of geodiversity and biodiversity and conduct activities with respect for the preservation of geological locations and formations that serve as evidence of the Earth's geohistorical evolution and monuments of geoheritage. As a result, local communities may continue their activities based on geoethical principles, allowing future generations to take advantage of the benefits (**Drinia et al., 2021**) without incurring negative repercussions or consequences.

Geological conservation raises a number of ethical difficulties stemming from a fragile equilibrium between human activities and the preservation of Earth's geological legacy. Mineral extraction, quarrying, and other human-caused activities frequently threaten geological formations. The ethical issues in geological conservation include the sustainable use of resources, the prevention of habitat destruction, and the preservation of unique geological features. The ethical argument in geological conservation revolves around striking a balance between using natural resources for human needs and preserving these resources for future generations. The ethical argument in geological conservation revolves around striking a balance between using natural resources for human needs and preserving these resources for future generations.

Moral awareness is critical in environmental protection, especially in the framework of geological conservation. Recognizing the intrinsic value of Earth's geological features and comprehending their importance for biodiversity, cultural heritage, and scientific knowledge is critical. The ethical obligation to safeguard geological monuments derives from recognizing the interdependence of the environment and human well-being. Moral awareness fosters sustainability by enabling people and their communities to make intelligent and ethical decisions in their interactions with geological settings. This raised moral consciousness motivates sustainable actions, affecting decision-making processes to ensure the permanence of geological legacy geological monuments.

When examining case studies that exhibit geoethical practices, several important results arise, shedding light on the relationship between geological heritage and ethical considerations.

**De Miguel et al., (2021)** discusses the changing environment of geoconservation and geoethics, with a focus on palaeontological heritage. As humans continue to have a greater impact on geoheritage, ethical concerns in paleontology become more pressing. To address these concerns, the term 'palaeontoethics' is coined, emphasizing the significance of ethical regulations tailored to the preservation of fossils and palaeontological sites.

**Gravis et al., (2020)** support community-led geoheritage and geoconservation initiatives in New Zealand. Understanding the constraints of general conservation methods, they recommend

that community-led initiatives based on international best practices provide a more sustainable model. Such initiatives not only promote low-impact tourism, but also offer educational and training opportunities that benefit local, regional, and national communities.

**Procesi et al., (2022)** present a case study from Rome, Italy, revealing how science and citizen partnership effectively turned a degraded urban site into an international center for knowledge, leisure activities, and ecosystem preservation. The study emphasizes the positive impact of geoethical principles on promoting responsible human-nature interactions, which improves citizens' quality of life.

These case studies collectively highlight the importance of incorporating ethical issues into geological conservation efforts, displaying creative methods and partnerships that have led to the sustainable preservation of geological heritage.

## Chapter 3: The Geological Heritage of Greece

### 3.1. Physiogeography of Greece

Greece is in southeastern Europe and has a crucial geographical position at the crossroads of Europe, Asia, and Africa. It is located on the Balkan Peninsula, bordering Albania, North Macedonia, Bulgaria, and Turkey (**Figure 8**). Greece has a diversified topography, including mountainous terrain, several islands, and a long coastline along the Aegean, Ionian, and Mediterranean Seas. The country has a total land area of around 131,957 square kilometers, ranking it as the world's 97th largest country by area. Greece's coastline is approximately 13,676 kilometers long, including the coastlines of its various islands, with estimates ranging from 1,200 to over 6,000 islands, depending on the criteria used to identify an island (size, surrounding water, political boundaries, geological formation, and accessibility). Crete, Greece's largest island, covers approximately 8,336 square kilometers.



**Figure 8.** The location of Greece in the southeast Europe

On one side of the country are high mountain ranges such as the Pindus and Olympus, while on the other side are wide plains and beautiful coasts on the Ionian and Aegean Seas. Greece's location on the globe has always been the reason for its trade, cultural interactions, and naval activities, which have given birth to a huge number of historical and cultural legacies. Besides this, its Mediterranean climate and status as a heaven on earth are also instrumental for it being a top tourist destination in the world. Based on a 2021 estimate, Greece had a population of about 10.3 million. In most urban centers, the leading population is concentrated in Athens, which is the capital and largest city. Thessaloniki, Patras, Heraklion, and Larissa are among the other significant cities. The population density differs from one place to another, the cities are more densely populated than the rural areas and the mountainous regions. Greece is a geological museum and natural laboratory for the geological scientific community, providing an exceptional

chance for investigating the subduction of the African plate beneath the Eurasian plate (**Drinia et al., 2021**). The excellent archaeological and cultural heritage of the country, together with the considerable geotectonic activity of the area, make it a destination where preservation and promotion are necessary.

### 3.2. Geological Setting of Greece

Greece is one of the regions come to witness the extremely but complex geodynamic activities at the intersection of different tectonic plates. For instance, the Hellenic Arc, which is situated along the southern margin of the Eurasian Plate, is one of the most seismically active zones in the world (**Papazachos et al., 2000**). The arc is formed by the convergence of the African Plate with the Eurasian Plate, which is represented by very active tectonics such as subduction, crustal extension, and mountain building processes (**Taymaz et al., 2007**). The existence of so many faults and the high seismicity in this area are manifestations of the ongoing tectonic processes (**Papadimitriou et al., 2018**).

Moreover, the geodiversity of Greece is also affected by the Aegean Sea which features the diverse interaction of Eurasian, African and Anatolian lithospheric plates, leading to the creation of several geological structures including mountains, basins, and volcanic centers are produced (**Doutsos et al., 2012**). The geodynamics in Greece, marked by the convergence of these plates and the occurrence of earthquakes, facilitate the enhanced learning of the natural mechanisms of the earth and the dangers posed by earthquakes in the Mediterranean region and other locations around the globe.

The geological development of Greece during the Late Cenozoic era has been influenced by the northward subduction of the African plate beneath the Aegean lithosphere (**Makris, 1977; McKenzie, 1970; Papazachos & Comninakis, 1978; Le Pichon & Angelier, 1979**), as depicted in **Figure 9**. As the African plate advances in a northward direction, horizontal shifts along the Dead Sea fault zone generate compression between the Arabian and Eurasian plates (**Molnar & Tapponnier, 1975**). This compression process leads to the thickening of the Earth's crust in Eastern Turkey. Consequently, both the Aegean and Anatolia plates are being pushed westward, resulting in the expansion of the Aegean region towards the eastern Mediterranean, a phenomenon referred to as gravitational spreading, as illustrated in **Figure 9**.

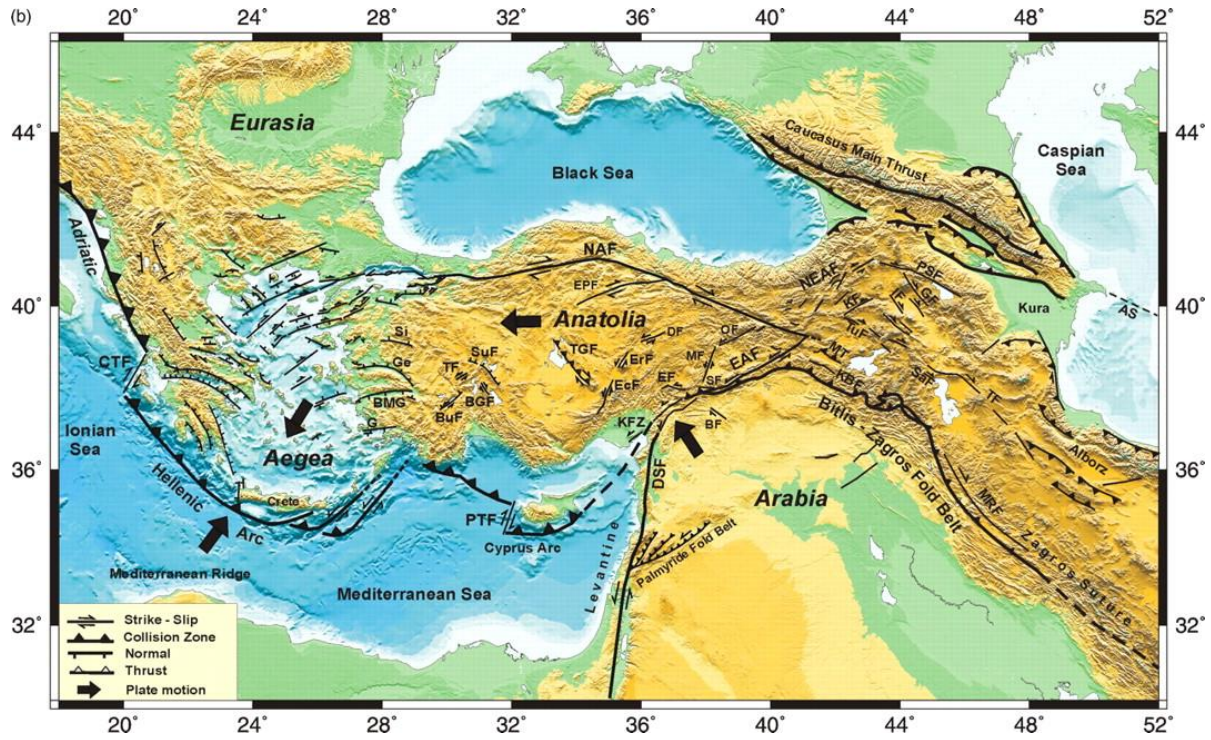


Figure 9. Sketch map depicting the geodynamic setting of Greece (Angelier & Pichon, 1980, modified)

The movement of the Aegean region towards the eastern Mediterranean through (Figure 10) gravitational spreading is confirmed by the existence of a concentrated network of normal faults dating back to the Upper Miocene period, as well as the presence of horst and graben structures (McKenzie, 1978; Pichon & Angelier, 1979; McKenzie, 1972; Angelier et al., 1981). As a consequence of this extensional faulting, there is a reduction in the thickness of the crust of the Aegean plate, which signifies crustal attenuation (Makris, 1978; Makris, 1985).

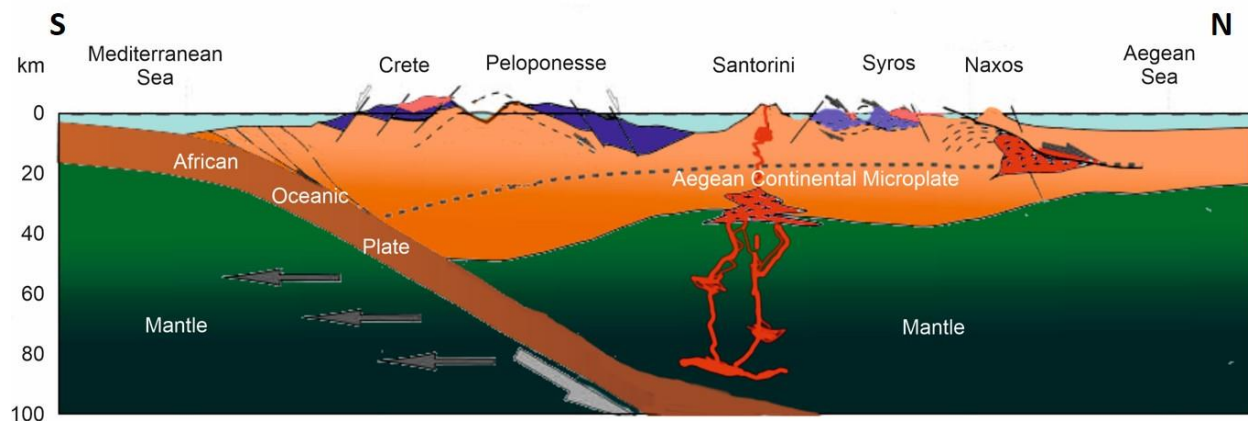


Figure 10. Schematic reconstruction of the northward dipping Hellenic Subduction system (after Trotet et al., 2001, modified)

For example, in the Cretan Sea, the thickness of the Aegean crust doesn't exceed 20 kilometers, indicating significant crustal stretching in that area. According to Makris, 1978; 1985, the Aegean region's crustal thickness varies, reflecting differences in the extent of stretching

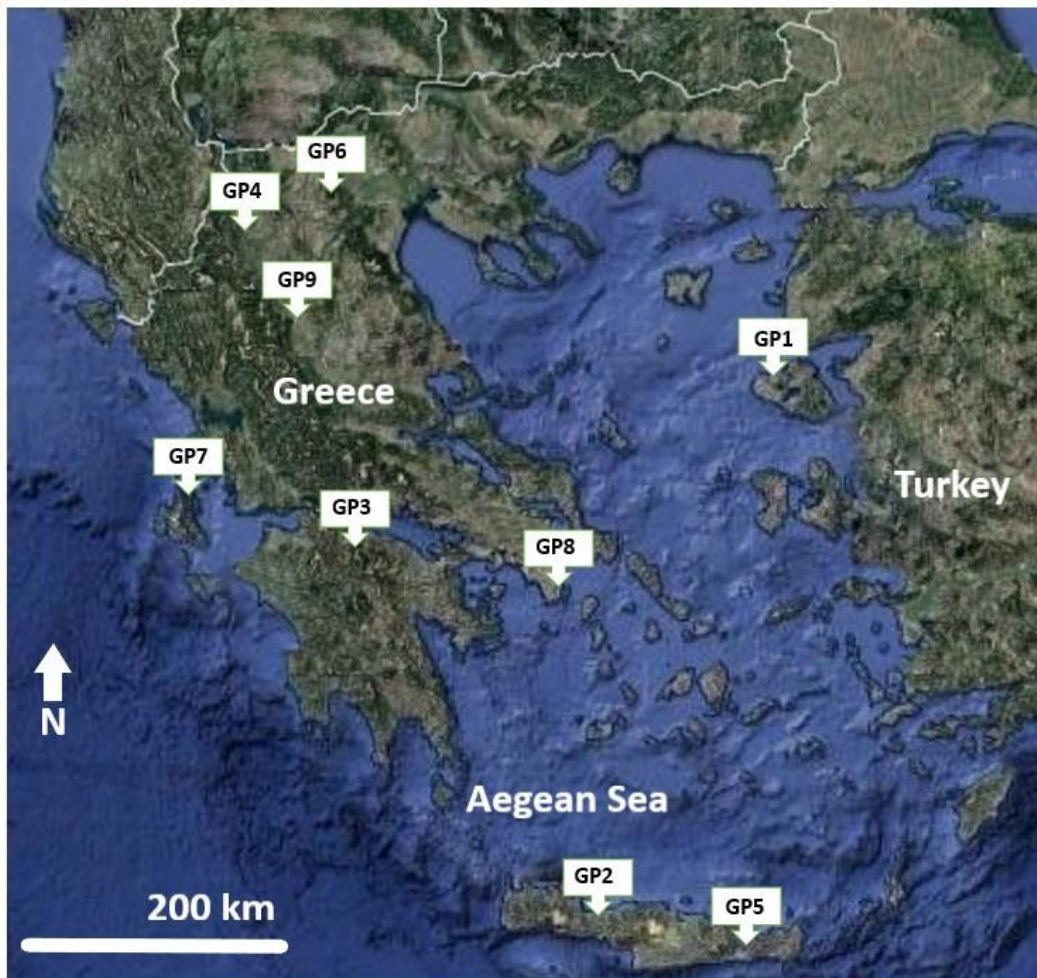
experienced by the Aegean crust. This variability is attributed to spatial variations in the tectonic activity within the Aegean plate. In addition to normal faults, the Aegean region has also been affected by rotational deformation since the Middle Tertiary period. **Angelier et al., (1982)** reported a 28-degree rotation of the Aegean region relative to Eurasia, with a pivot point located in the southern Adriatic Sea. This rotation led to the gradual extension of an internal landmass and the continuous adaptation of the Hellenic Trench to this extension (**Jarnet, 1982**). Another clockwise rotation of 26 degrees occurred in western and northwestern Greece since the boundary between the Miocene and Pliocene epochs (around 5 million years ago) (**Laj et al., 1982; Valente et al., 1982**). Paleomagnetic studies indicate that this rotation did not impact the southern and southeastern parts of the Hellenic Arc, encompassing Crete and Rhodes. This suggests the presence of a structural discontinuity between the western and eastern segments of the Hellenic Arc (**Mercier et al., 1976**). Due to this discontinuity, the western segment of the Hellenic Arc experienced a compressional phase since the boundary between the Miocene and Pliocene epochs. This compression may be associated with the continental collision between the Aegean domain and the Apulian continental margin, located west of the Ionian Sea (**Sorel, 1976; Paquin et al., 1984**). Conversely, the southern segment remained predominantly under extensional conditions, with intermittent periods of compression (**Taymaz et al., 2007**).

While the Aegean region is characterized by extensional tectonics, resulting in continuous subsidence, the Hellenic Arc exhibits an elevated position in relation to the Cretan Sea to the north, as depicted in **Figure 9**. **Angelier & Le Pichon, (1980), Angelier, (1981), Huchon et al., (1982),** and **Angelier et al., (1982)** have attributed this uplift of the Hellenic Arc to a process known as crustal underplating, which has been occurring since at least the Middle Miocene period. This implies that sediments from the subducting African plate have been removed to create the new foundation of the Hellenic Arc (**Barton et al., 1983**).

### 3.3. The Geological Heritage of Greece

As previously stated, Greece has a diverse range of geological features and formations that are important for global science and research. This is primarily due to its position at the convergence point of two tectonic plates, the African and Aegean microplates. Accordingly, geologists' view all over the globe is that Greece is a natural geological laboratory endowed with crucial information concerning global geodynamic processes. This place is becoming more prominent for several reasons. These involve frequent earthquakes, volcanic activity, a variety of processes that deposit sediment, and changing coastlines. Moreover, Greece serves as a vast geological monument as it safeguards key stages of the Earth's active evolution, from the Proterozoic era to the present. The geosites capturing these major geological milestones are "parts of the geosphere that have a special meaning for the understanding of Earth's history" (**Goudie, 2004; Theodosiou et al., 2006**). These geosites, or geotopes as they are also known, are of great importance in science, have great aesthetic and cultural value, and serve as essential ecological

areas. Unfortunately, lack of awareness often results in irreversible destruction of these valuable geosites. Meteora, Mount Olympus, the Samaria Gorge in Crete, the ancient Lavrion mines within the Sounion National Park, the Petrified Forest of Lesvos, the Vicos and Aoos Gorges in Epirus, the Diros Caves in Peloponnesus, the Santorini Volcanic Caldera, the Prespes Lakes in West Macedonia, and the Falakron Mountain—Aggitis Karstic System in East Macedonia are among the most well-known geosites in Greece. These sites are not only well-known but also legally protected and developed tourist attractions, drawing thousands of visitors annually (**Drinia et al., 2021; Zouros et al., 2003**). Furthermore, Greece is home to nine of UNESCO's global geoparks, including Lesvos Geopark, the Vikos–Aoos Geopark in Epirus, the Chelmos-Vouraikos Geopark in Peloponnese, the Psiloritis Geopark on Crete, the Sitia Geopark on Crete, the Grevena–Kozani Geopark, the Kefalonia-Ithaca Geopark, the Lavreotiki Geopark and Meteora Pyli Geopark (**Figure 11**).



**Figure 11.** Satellite photo of Greece, indicating the location of Geoparks: GP1—Lesvos, GP2—Psiloritis, GP3—Chelmos-Vouraikos, GP4—Vikos-Aoos, GP5—Sitia and GP6—Grevena-Kozani, GP7—Kefalonia-Ithaca, GP8—Lavreotiki, GP9—Meteora Pyli

The systematic promotion and geosite protection efforts in Greece started back in 1995, which is a huge step in the geological heritage preservation (**Drandaki, 1995; Drandaki & Mettos, 1996**). During that time the whole set of initiatives for the protection and popularization of the geological heritage came about, through which concepts such as geological heritage conservation, geoconservation, geosites, geotopes, geodiversity, and geoparks emerged (**Theodosiou-Drandaki, 2000**).

A pivotal moment occurred in 2005 when the IGME Board decided to allocate funds from the 3rd Community Support Framework (CSF) for the designation of geosites and geoparks, signifying a turning point in the recognition and support of these geological treasures.

The shift towards the inventorying process and the promotion of geoconservation activity in Greece, together with the strategies for the conservation and enhancement of geodiversity in certain sites, was a challenge that required joint efforts to overcome them (**Dorset County Council, 2005**). This initiative, inspired by the 'Action Plan' process implemented in two areas, Lavreotiki and Vikos-Aoos, was aimed at assessing management requirements for various geodiversity elements, establishing long-term objectives, setting short-term targets, and allocating the required human and financial resources (**JNCC, 2004**). It took a decade to transform the concept of geological heritage conservation into tangible actions, reflecting the time required for new ideas to gain acceptance (**Theodosiou, 2007**). However, as the saying goes, "A mind once expanded with a new idea never regains its original proportion." By 2005, the Institute of Geology and Mineral Exploration (IGME) had ten years of experience promoting geological heritage through education and training (**Drandaki et al., 1999**). With a broad range of geoscientific knowledge, competent staff, and established infrastructures IGME was well-suited for managing this new research project. IGME, as a key collaborator of UNESCO, the International Union of Geological Sciences (IUGS), and ProGEO, played an important role in coordinating geoscience efforts both nationally and internationally (**Theodosiou-Drandaki, 2001**). IUGS launched the "Geosites" initiative in 1996 with the goal of systematically inventorying the most significant geological monuments worldwide, emphasizing the importance of geodiversity conservation, a non-renewable resource required for scientific research and education (**ProGEO and Wimblendon et al., 1998; Theodossiou-Drandaki, 2000**). Within this broader context, efforts to conserve geosites and establish geoparks gained traction, laying the groundwork for long-term geological heritage conservation (**Drandaki, 1996; Theodossiou-Drandaki & Foundou, 1997**).

In 2022, the International Union of Geological Sciences published a list of its first 100 Geological Heritage Sites. Among these, the Lesvos Petrified Forest is one of the world's most important fossil forest sites, known for its exceptional preservation and designated as a Natural Monument. Its formation is closely related to volcanic activity in the Aegean during the Early Miocene. With ancient roots, this site is historically significant because it was one of the first locations where philosopher Theophrastus (371BC-287BC) mentioned the fossilization process. Recognized as one of the pioneering European geoparks in 2000, it is a prominent geoeducation hub that contributes significantly to raising national and global awareness of geological heritage.

The list also includes Santorini's caldera. The caldera, formed by Plinian eruptions inside a volcanic arc tectonic framework, is one of the Mediterranean Sea's largest. It demonstrates the great strength of volcanic activity, as represented by the classic Minoan Eruption, which happened approximately 3600 years ago and is considered one of the most damaging eruptions in recorded history. This cataclysmic catastrophe is thought to have contributed to the decline of the Great Minoan Civilization, with long-term consequences for Greek mythology, archaeology, and volcanology. The strata of the caldera walls reflect the complicated history of several eruptive episodes, shedding light on volcanic processes. The entire caldera area has exceptional geological and natural features, making it an active laboratory for earth science research, volcanic risk assessment, and monitoring.

As a result, Greece's geological heritage is vast and varied, offering valuable insights into global geodynamic processes. With continued efforts, Greece can protect its geological legacy for future generations while also inspiring scientific research and education around the world.

### 3.3.1. The UNESCO Global Geoparks of Greece

Greece's UNESCO Global Geoparks are significant geological and cultural landscapes of international importance. Greece currently has nine UNESCO Global Geoparks, each with distinct geological features, biodiversity, and cultural heritage. These UNESCO Global Geoparks are critical for promoting geological heritage, sustainable tourism, and local development, as well as cultivating an appreciation for Greece's unique geological and cultural landscape.

The UNESCO Global Geopark on Lesvos Island was established in 2000 and has been part of the European Geoparks Network. Additionally, it joined the Global Geoparks Network in 2004 and was originally named the Lesvos Petrified Forest Geopark. Within this geopark lies an ancient forest that was remarkably preserved by a massive volcanic eruption that occurred approximately 20 million years ago. Furthermore, significant discoveries near the Lesvos Island UNESCO Global Geopark include the remains of the oldest known proboscidean, *Prodeinotherium bavaricum*, which dates back 19 million years to Greece. The area also contains impressive fossils of animals that lived on Lesvos approximately two million years ago. Additionally, many volcanic sites and thermal springs point to strong volcanic activity between 21.5 and 16.2 million years ago. In the end, the geopark has geological faults and landscapes that tectonic processes shaped.

The Psiloritis UNESCO Global Geopark set up in 2001, sits on Crete, a Greek island, and covers about 1200 square kilometers. It covers the whole central part of the island, including Mountain Idi (Psiloritis), Crete's highest point at 2456 meters. This geopark is well-known for its remarkable geodiversity, which is represented by a diverse range of volcanic, sedimentary, and metamorphic rocks dating from the Permian to the Quaternary Period (300 to 1 million years ago). The geopark also contains striking folds and faults, attractive caves, and vast canyons, all of which are home to a variety of species. These geological features are prominently displayed in a variety

of well-exposed outcrops and cross-sections, revealing important information about mountain formation processes (**Fassoulas & Zouros, 2010**).

The Chelmos–Vouraikos UNESCO Global Geopark, established in 2009, is situated in the northern part of the Peloponnese region in Greece, approximately 200 kilometers away from Athens. Chelmos mountain has changed over millions of years through many unique changes caused basically by natural forces, especially the omnipresent force of water. These metamorphoses have created a large variety of wonders in the geopark such as the majestic Vouraikos Gorge, the magical Cave of the Lakes, the clear springs of Aroanios River, the mythical waters of Styx and the beautiful Tzivlos and Doxa lakes. Not only that, but their lakes are not just on the surface, but below the ground too. The Cave of the Lakes offers the unique opportunity to explore three out of its thirteen subterranean lakes (**Golfinopoulos et al., 2022**).

The Vikos-Aoos UNESCO Global Geopark became part of the UNESCO Global Geoparks in 2010 and is located in the Ioannina region of Epirus, northwestern Greece. This geopark, located in the northwestern section of the Pindus Mountain Range, is distinguished by its elevated and rugged terrain, resulting in a breathtaking and impressive landscape. Within its boundaries, prominent features include Mt. Smolikas, Greece's second-highest peak at 2637 meters above sea level, and Mt. Tymfi, which rises to 2497 meters (asl). Notably, the geopark includes two remarkable gorges: Vikos and Aoos. The geological composition of the Vikos–Aoos UNESCO Global Geopark consists of deep-sea sedimentary rocks that underwent folding and faulting due to powerful compressive forces that prevailed in the Greek region approximately 20 million years ago. These forces were the result of the collision between the African and Eurasian tectonic plates. Additionally, the geopark features an ophiolitic complex as one of its geological components (**Stergiou et al., 2019**).

The Sitia UNESCO Global Geopark joined in 2015 the UNESCO Global Geoparks and is located at the eastern end of Crete and is characterized by an abundance of Pleistocene mammal fossil sites. It is famous for the three *Deinotherium proavum* fossils found there and for its vast amount of cave systems and prehistoric coastlines. The most distinct geological feature about this geopark is that it has so many karst features all throughout its limestone terrain. So far, the region has produced more than 170 caves, and many gorges, demonstrating its geological diversity (**Fassoulas et al., 2013**).

The Grevena–Kozani UNESCO Global Geopark, established in 2021, is one of the places of geological heritage that is connected to the origin of the plate tectonic theory. It also stands as a monument to the lasting power of this geological legacy in creating unbelievable landscapes and unique biological communities. Within this region lie the oldest rock formations ever unearthed in Greece, along with locations that provide insights into the geological chronicles and rifting mechanisms associated with the formation of the Tethyan Ocean and the emergence of Europe as a separate continental landmass (**Rassios et al., 2016**).

The Kefalonia-Ithaca UNESCO Global Geopark (was found in 2016) on 13th April 2022 joined the UNESCO Global Geoparks and more specifically the geological positioning of these islands is situated at the junction where the Greek arc's convergence zone transitions into the collision zone involving the Adria plate. This is especially shown by the counterclockwise rotation of the underwater fault block underneath Kefalonia. Kefalonia Island is located in a unique location where it sits right on the active plate boundary between the European and African plates, it is a place where oceanic and continental subduction occurs. As a consequence of their geotectonic placement, all of these islands experience high levels of seismic activity. Regarding their geological structure, the islands are characterized by post-alpine formations, including the sedimentary alpine Paxos and Ionian geotectonic units that are part of the external Hellenides (Spyrou et al., 2022).

The Lavreotiki UNESCO Global Geopark (since 2023), 60 km southeast of Athens, Greece, is really an unknown treasure. It covers a geological, geomorphological, and culturally significant area. Today, the area is home to about 25,102 people, but it has a history of human occupation going back to prehistoric times, due mostly to its subterranean geological wealth. On a global scale, the geopark is renowned for its diverse sulfide ore deposits, the extraction of silver, and its remarkable collection of mineralogical specimens, many of which are recognized as type-localities (Voudouris et al., 2021). This geodiversity is linked with the geopark's extraordinary natural beauty and biodiversity (Moraiti, 2018).

Geopark of Meteora – Pyli, Greece, joined in 2024 in the UNESCO Global Geoparks Network. It worths mentioning that it was renowned for its scenic beauty and historical significance as a UNESCO World Heritage site since 1988. This geologically distinct region consists of enormous conglomerates, standing tall after millions of years, as they soar in the air from the Thessalian Plain. Not only this is a geological wonder, but it is a place of great cultural heritage because these cliffs are home to several Eastern Orthodox monasteries that are perched on the sides of these cliffs. There are 21 geosites in the Geopark, and it has a variety of flora and fauna, so it is a perfect place for nature lovers and hikers. There are numerous trails that lead through the green woods and around old caves, providing stunning views of the surrounding landscape. This Geopark, with its geological attractions, history, and spiritual atmosphere, is an essential destination for anyone interested in scenic beauty and geoheritage (Georgousis et al., 2021).

### 3.4. Institutional Framework–Legislation

The legislation of Greece for protecting geoheritage has changed over time to conserve and manage sites of scientific, cultural, and environmental significance.

Law 4173/1929 established guidelines to protect forests and forest welfare, while Law 5351/1932 focused on antiquities, with its supplementary Law 1469/1950 allowing for the

protection of scenic landscapes. Law 5343/1932 established guidelines for fossil excavations, and Law 856/1937 specifically addressed the conservation of geomorphological formations. Since 1937, Greece has identified natural areas and implemented special protection measures for them through a variety of means, including national laws, international agreements, and efforts at both the European and global level. Legislative Decrees 86/1969 and 996/1971 created the category of natural monuments under protection.

The first constitutional provision for environmental protection is found in Article 24 of the 1975 Constitution (Law 177/75, later revised by Law 2637/1998), which introduced measures for wildlife sanctuaries, controlled hunting areas, and game breeding stations. Caves were classified as monuments under the Ministerial Decision of the Ministry of Culture and Tourism/AI/F45/18378/650/1983, subject to the aforementioned law on antiquities. The Lesvos Petrified Forest was designated as a protected natural monument in 1985, with specific preservation conditions outlined. Law 1650/86 'For the Protection of the Environment' created a new category of protected areas that went beyond forests to include nature and the landscape in general. This legislation sought to establish an appropriate framework for protecting and promoting environmental assets of high geological and geomorphological value. The Environmental Protection Law was enacted in response to these developments. In accordance with the standards set by the International Union for Conservation of Nature (IUCN), Law No. 1650/86 established five distinct categories for these protected areas:

- i. Absolute Nature Reserve Area.
- ii. Nature reserve Area.
- iii. National Park.
- iv. Protected significant natural formation and protected landscape.
- v. Ecodevelopment Area

Before 1986, specific geological monuments, known as geotopes, received protection through forest and archaeological legislation. Despite being well-documented and recognized, Greece does not have official protection measures in place for its geological heritage. Greece has approved every pertinent international agreement, and its institutional framework guarantees that even individual geotopes in areas with potentially inconsistent growth procedures, such as urban environments or industrial parks, can be safeguarded and enhanced. The Biodiversity Law 3937/2011 has significantly strengthened the protective framework previously established by Law 1650/86, particularly in the field of "natural formations-landscapes-components of landscapes." This law primarily safeguards functional elements of nature or human-made creations with scientific, ecological, geological, geomorphological, or aesthetic significance. This comprehensive approach contributes to the conservation of natural resources as well as the preservation of natural processes.

Regardless of efforts by scientists and others, Greece lacks a national geosite inventory. The first organized effort to document geological monuments took place in 1982, under the umbrella of the Institute of Geology and Mineral Exploration (IGME), which represented the

Ministry of Culture. However, the early initiative concentrated on the monumental aspects of the chosen geomorphic features. UNESCO's GEOSITES program took a more comprehensive approach, aiming to create a global geosite catalog. In Greece, the Greek Geosites project was launched by the Institute of Geological and Mineral Research (IGME), which also coordinated the Southeast Europe Working Group within the ProGEO Executive Secretariat (**Theodosiou et al., 2006**). In 1995, IGME attempted to create a working group focused on protecting Greece's geological heritage. This effort expanded over time, involving scientists from universities and other institutions. IGME has made substantial contributions to safeguarding Greece's national geoheritage, encompassing geotopes, geopaths, and geoparks. They have created extensive management plans for recording and promoting these sites. One notable initiative by IGME in 2005 was the incorporation of a project in the Third Community Support Framework. This project is designed to methodically record geotopes based on their geological, educational, or tourist value while also identifying potential geoparks. Since then, the issue has been integrated into several sub-projects of the National Strategic Reference Framework (NSRF). This ongoing effort has resulted in the wrapping up of a systematic inventory project and the creation of an interactive Geographical Information System (GIS). The GIS provides detailed geospatial data, metadata, and information about both European geoparks and Greek geopaths investigated by IGME.

In 2004, the Geological Society of Greece founded the Commission for the Advancement of Geological and Geomorphological Heritage with the aim of overseeing scientific efforts in the field of geoconservation.

The initial effort to initiate a public dialogue regarding the preservation of Greece's geological heritage occurred in 1996 in Ermoupolis, Syros. Subsequently, in 2000, the terminologies related to this subject were formalized by the Academy of Athens. This development marked the recognition of a more structured approach to documenting potential geotopes, with the intention of designating some of them as geoparks.

### 3.5. Geotourism development in Greece

The tourism industry is critical to Greece's GDP and contributes significantly to the economy. According to recent statistics, tourism accounts for roughly 20% of Greece's GDP. When indirect contributions and related sectors are taken into account, the overall impact of tourism on the Greek economy increases significantly. Based on the most recent data, the tourism sector contributes approximately €37 billion to Greece's GDP annually.

Recent research indicates that Greece has attracted an additional nine million tourists over the past five years (excluding cruise tourists), with aspirations to further establish itself at the forefront of global tourism. In 2016, Greece ranked 14<sup>th</sup> in the world tourism organization's rankings, based on international arrivals. Over the last thirty years, Greek tourism has experienced rapid development, transitioning from elitism to mass tourism, largely driven by technological

advancements that have bridged distances (**Igoumenakis, 1999**). This expansion has been aided by a variety of factors, including longer vacation periods, economic growth, advancements in transportation services, growth in urbanization trends, advances in technology, cultural evolution, increased enthusiasm, and the joint efforts of the public and private sectors to address tourism-related issues. Additionally, there has been a redefinition of the Greek hotel sector. Even though Greece holds a prominent position among the leading Mediterranean countries, following Spain, Italy, and Turkey, in terms of competitiveness, the Greek tourism industry faces significant challenges, stemming from both its structural characteristics and inherent weaknesses, compounded by strong international competition.

In recent years, alternative forms of tourism have flourished in our country, offering the tourist population the opportunity to enrich their tourist activities and participate in specialized programs within the framework of religious, spa, ecotourism, cultural tourism, agrotourism, and other forms of alternative tourism, as analyzed and presented above (**Christou, 1999**). Geotourism presents a "new" challenge for Greece. Not only can it redistribute the country's tourist product to areas that have not traditionally been tourist destinations, but it can also stimulate a new quality of tourism in the country. Geotourism serves as a valuable tool for highlighting and developing a region, provided it is utilized correctly and, above all, with prudence.

Since geological and geomorphological sites of tourist interest are encountered broadly in the Greek countryside and are scattered throughout the Greek territory, inspiring awe and admiration where they are preserved and recognized, the development of geotourism is feasible in all regions of our country. The broad geographical distribution of geological and geomorphological sites, as well as the global recognition of significant locations as Geological Monuments, have the potential to drive regional development in the areas where they are located (**Sturm, 1996**). According to **Skentos (2012)**, Crete is Greece's most active geotourism hub. The South Aegean region is also well-known for geotourism. Meanwhile, the Ionian Islands and Attica regions have moderate to high geotourist activity. In contrast, Epirus, Peloponnese, and Thessaly have intermediate levels of geotourism activity.

The benefits from this development can be manifold:

- ✓ Economic benefits for local populations,
- ✓ National benefits due to the revitalization of the Greek countryside, particularly in mountainous and remote areas that host geological monuments that may be their sole economic resource,
- ✓ Demographic benefits stemming from the resolution of the livelihood problem for young people in specific areas, by providing employment and new opportunities,
- ✓ Social benefits from preventing migration and uprooting a satisfactory number of people from their birthplace and origin,
- ✓ Educational benefits as outdoor museum exhibition spaces and educational programs are created,

- ✓ Environmental benefits as the development of certain geological monuments will lead to the establishment of mechanisms for their protection and preservation.

What matters, therefore, is the implementation of a **management plan** focusing on the protection and promotion of the geocultural heritage of an area, as well as informing and raising awareness among citizens about the sustainable tourism development of the area. This, however, presupposes "the research, conservation, and documentation of the geoheritage, the inventorying, evaluation, and protection of geodiversity, informing and sensitizing the population and visitors of geosites, and sustainable tourism development by creating appropriate infrastructure for tourism, cultural, and scientific events and activities" (**Lampaki & Zouros, 2007**).

According to **Bathrellos (2000)**, the **Management Plan of Geological Monuments** should include:

- ✓ Characteristics, problems, and special values of the protected geological monument,
- ✓ Description of the causes and reasons that led to its establishment,
- ✓ Means for its rational and effective management,
- ✓ Public information and education through brochures, special features in print and electronic media, souvenirs, seminars, conferences, etc.
- ✓ Conservation, reformation, and restoration of significant geosites and geological natural monuments, where feasible and necessary,
- ✓ Cleaning of exhibits,
- ✓ Supervision and guardianship,
- ✓ Determination of measures for the better use of personnel, resources, and various supplies available to managers,
- ✓ Appointment of management bodies.

As a result, Greece's geosites may have an important role in boosting the country's tourism industry by providing a low-cost local tourism product that promotes regional development. Geotourism serves a novel opportunity for Greece because it has the potential to redistributing tourism to previously underserved areas while also attracting a higher-quality tourist population. The conventional geotourism activities in Greece encompass cave tourism (specifically in tourist caves) and hot spring and spa tourism (**Georgakopoulou & Delitheou, 2020; Karamani et al., 2019**). Nevertheless, Greek geosites can support a broader spectrum of activities catering to diverse audiences.

Greece has made significant advancements in promoting and managing its geological heritage in recent years, thanks to the Geological and Mineral Exploration (IGME) project. This initiative seeks to document geosites, create georoutes, and promote Geoparks worldwide. The IGME's GIS system offers a user-friendly platform for displaying geospatial data on Greek and European geotopes. Greece's efforts to preserve and promote cultural assets are strengthened by incorporating geological heritage protection into NSRF programs. The interactive GIS system

raises public awareness and promotes geological heritage as a valuable educational resource. For example, more than 250 geotopes have been documented on the island of Milos, serving as important witnesses to past and ongoing processes on Earth's surface. These geotopes, together with the area's historical, cultural, archeological, and ecological features, as well as beautiful natural landscapes, comprise 12 Geotrails.

Greece is in a particularly advantageous position as significant prospects for attracting visitors arise from its eight Geoparks, designated as UNESCO Global Geoparks. Geoparks offer sustainable tourism development as they are not subject to seasonality and attract tourists and individuals interested in geological sciences throughout the year. Most of Greece's Geoparks have already developed domestic tourism. However, Geoparks are not solely perceived as geotourism destinations by visitors. They offer a combination of activities such as nature exploration, visits to monuments and traditional settlements, summer vacations, and more. Market experts emphasize that geotourism in Greece's eight Geoparks can serve as a significant extension of the tourist season and can directly attract cumulatively, due to the country's location and microclimate, more than 1,000,000 tourists annually.

Broadly speaking, geotourism has the potential to become a key element of rural tourism in Greece. For this reason, the corresponding ministry of tourism could be taking further steps in this direction. In this way, the Greek economy can benefit greatly. More specifically, in many instances, this "geotourism offering" is integrated into the broader spectrum of rural tourism experiences (**Newsome & Dowling, 2010**), which encompass agrotourism, cultural tourism, and adventure tourism, and therefore, it shouldn't be treated as a standalone entity. Additionally, there are scenarios where the "geotourism offering" can complement the nation's primary tourism product, particularly when the prevalent and widely favored form of tourism (sun and sea) evolves towards sustainable tourism development, gaining differentiation and enrichment in the process.

### 3.6. Geoeducation in Greece

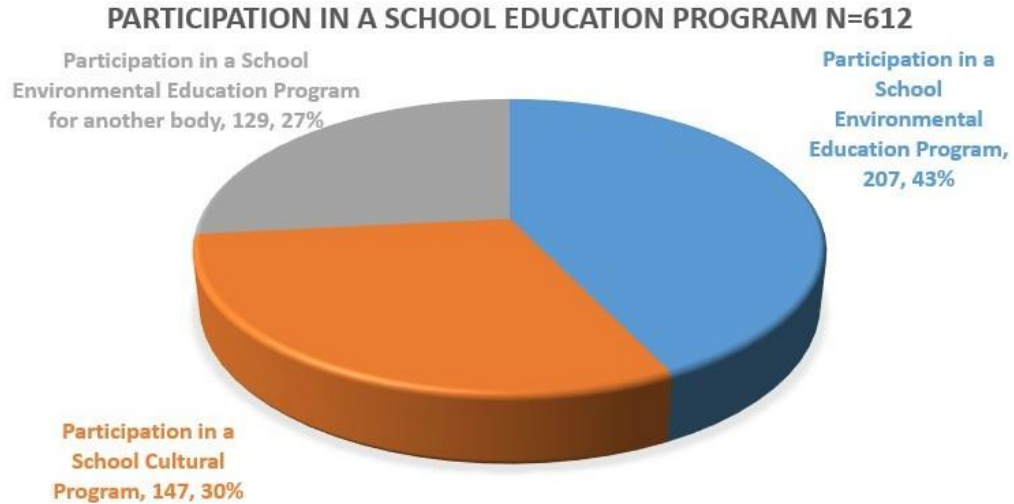
As previously stated, geoeducation aims to teach people about science subjects such as geology, geography, and environmental studies. This includes both formal education at universities and informal learning experiences like museums, nature centers, and field trips. The goal is to gain a better understanding of Earth's processes, resources, and how people interact with the environment. Geoeducation contributes to societal issues by increasing knowledge, promoting sustainability, and facilitating informed decision-making about natural resources and hazards. The ultimate goal is to create a scientifically literate society capable of dealing with geological issues and protecting the planet. Geoeducation is incorporated into educational systems around the world, at all levels, from primary to tertiary.

Geoeducation is critical for promoting public awareness of geological and geomorphological heritage, especially in the context of sustainable tourism initiatives such as

geotourism. Geotourism, in turn, serves as a catalyst for geodiversity conservation by disseminating Earth science knowledge and encouraging appreciation for geological characteristics among a diverse audience. Geoeducation is critical for raising societal awareness of the intrinsic value of geological and geomorphological heritage. It promotes the use of nonformal learning activities, such as geoheritage interpretation, as effective tools for involving people of all ages in the management and conservation of geoheritage sites.

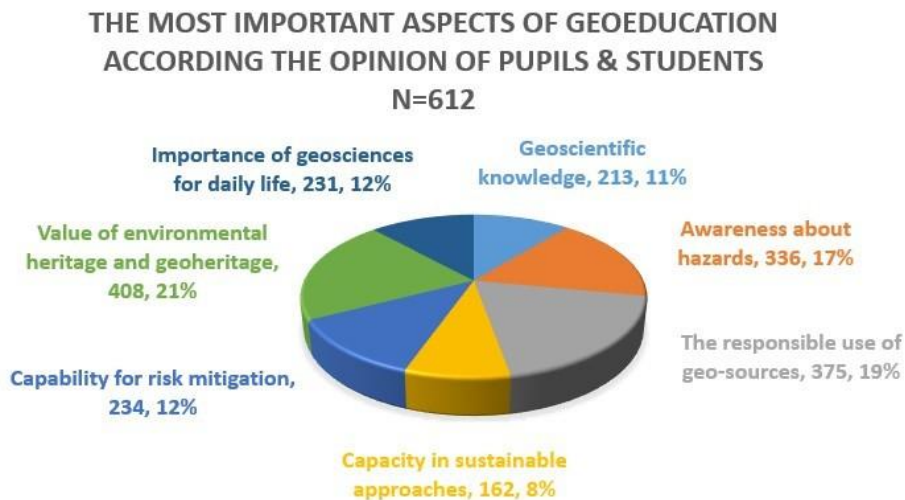
Specific case studies in the Municipality of Castellarano, Italy, show how local administrations, stakeholders, and researchers collaborated to create territorial strategies focused on geoheritage management and sustainable use (**Vandelli et al., 2023**). These initiatives include the creation of interpretive materials and guided excursions designed to educate both general visitors and geotourists about the area's geological and geomorphological significance. Geoeducation is clearly necessary for promoting greater knowledge and appreciation of geological and geomorphological heritage, thus contributing to its long-term conservation and sustainable enjoyment.

This knowledge is integrated into the geography curriculum in Greek primary schools. However, this course is frequently taught by instructors who lack specialization, and it is occasionally integrated into topics of study (**Rokka, 2018**). In addition, in higher education, specifically in the first and second grades of high school, Geology and Geography are limited to one and two hours per week, respectively. These curricula do not adequately emphasize concepts such as geoheritage, the paleontological significance of specific geological monuments, and fossilized areas that provide insights into the planet's evolution (**Meléndez et al., 2007**). Consequently, Greek students receive insufficient education on geological and geoenvironmental topics, which are essential for their daily lives. As a result, after finishing elementary school, students frequently do not have a fundamental knowledge of geosciences, which are extremely relevant to citizens' daily lives (**Trikolas & Ladas, 2013; Fermeli, 2011**). **Georgousis et al., (2021)** found that many Greek schoolchildren and students lack knowledge and appreciation for geoheritage and its importance to society. This study emphasizes the importance of introducing and implementing geoenvironmental education, rather than limiting the focus to environmental education. Furthermore, it emphasizes the importance of well-trained educators in Greece's educational system who can effectively communicate important knowledge and the significance of geoenvironmental principles to students. According to **Georgousis et al., (2021)**, who surveyed 612 pupils and students, there was initially a lack of student participation in geoenvironmental education programs. However, the study's findings revealed that 43 percent of students participate in school-based environmental education programs, 30 percent in cultural educational programs, and only 27 percent in educational programs conducted outside of regular school activities (**Diagram 1**).



**Diagram 1.** Pie chart regarding of the results of student participation in various school educational programs, based on Georgousis et al., 2021

Moreover, the results of **Georgousis et al., (2021)** study hold significant implications regarding the key aspects that arise from the implementation of geoeducation. Twenty-one percent of respondents indicated that geoeducation is linked to environmental heritage and geoheritage (**Diagram 1**). According to 19% of participants, geoeducation pertains to the responsible utilization of geological resources. Seventeen percent of respondents associate geoeducation with awareness of geological hazards. A 12% segment relates geosciences concepts to everyday life and the ability to mitigate risks. Finally, 11% of participants expressed that geoeducation is connected to a broader understanding of geoscientific knowledge (**Diagram 2**), while 8% believe it is associated with the capacity for sustainable practices (**Georgousis et al., 2021**).



**Diagram 2.** Pie chart regarding of the most important aspects of geoeducation as reported by 612 pupils and students (Georgousis et al., 2021)

The Greek education system clearly falls short in providing adequate geoenvironmental knowledge, resulting in the younger generation not understanding the importance of preserving geological heritage. Recognizing the value of Greek geological heritage may have broader implications for various aspects of Greek society, such as cultural and archaeological preservation.

## Chapter 4: Exploring the Geodiversity of Kalymnos, Nisyros, and Samos Islands

### 4.1. Introduction

The non-profit islands of Nisyros, Kalymnos, and Samos in the eastern Aegean Sea have unique geological features that shed light on the Earth's dynamic processes. Nisyros' landscape is well-known for its volcanic origins, which resulted from continuous volcanic eruptions. This creates a diverse landscape. Kalymnos, with its rugged terrain and limestone formations, offers a glimpse into its complex geological history. Samos' diverse landscapes reflect the interaction of tectonic forces and climatic influences that shaped its geological features.

These islands have been home to geosites and geological monuments that point out their diverse geological history. These geosites, which include high cliffs and complicated mineral patterns, provide insight into the region's geology. Nevertheless, safeguarding these geological assets presents significant challenges. Balancing geotourism, which can help local economies, with the need to protect these fragile geosites necessitates sustainable management practices. Effective strategies must be implemented to ensure the ongoing preservation of these geological wonders while also promoting their educational and economic value.

This study examines the geological features and conservation challenges of Nisyros, Kalymnos, and Samos in order to better understand and protect the islands' unique geological heritage. It hopes to protect these natural treasures for future generations by investigating their geological features in depth and implementing sustainable practices.

Previous studies on the islands of Kalymnos, Nisyros, and Samos have greatly improved our knowledge of their geological characteristics and geosites. In Kalymnos, **Zafeiropoulos and Drinia (2021)** extensively examined the potential for geotourism development, highlighting the importance of systematic geosite information collection and analysis. The study emphasized the importance of effective geoheritage conservation and management strategies, and it presented a SWOT analysis that showed the potential for geotourism and related services in Kalymnos, such as recreation and geoeducation activities.

For Nisyros, **Zouzias et al., (2011)** provided helpful insights into the interpretation of the volcanic terrain using land surface parameters generated by the ASTER Global Digital Elevation Model. They discovered new volcano-tectonic features, such as the segmentation of Nisyros into three northwesterly trending sectors and its inclination toward southeast. In addition, **Nomikou & Papanikolaou (2011)** used onshore and offshore data to expand their comprehension of active fault zones on Nisyros volcano across the Yali-Nisyros Channel.

**Nomikou et al., (2021)** investigated volcanic relief in the Kos-Nisyros-Tilos Tectonic Graben, shedding light on geological characteristics and geohazard implications. Their research

combines data from previous marine geophysical and ROV surveys with geospatial techniques to generate synthetic maps of vast underwater areas.

These surveys contribute to a deeper understanding of the geological heritage. Geological diversity and potential terrestrial hazards are associated with these islands. This paves the way for future conservation and management initiatives.

## 4.2. Physiogeography of the study area

Our study focuses on two islands of the non-profit line of the southeastern Aegean (Kalymnos and Nisyros) and the island of Samos in the North Aegean.

As it is already mentioned, the term 'non-profit line' refers to the route of a vessel that has neither commercial nor passenger traffic and thus no business interest on the side of shipowners or shipowners. To provide transportation services to the destinations supported by these lines in Greece, which are predominantly island regions, the state must support these routes and launch vessels via a contract process. Based to this Decree, the Council of Ministers designates unproductive routes as "main," "postal," and "tourist". The Ministry of Merchant Shipping (MoC) conducts tenders for unprofitable lines, and contracts are made between the State and the ship owners or shipowners who have been shortlisted for each unprofitable line. The main non-profit lines are currently present in the Cyclades and the Dodecanese. Nisyros and Kalymnos are part of the Dodecanese Island complex, while Samos is in the North Aegean Prefecture.

The Dodecanese Island complex in the southeastern Aegean Sea is physically characterized by its proximity to Turkey's southeast to the east, Crete to the southwest, and the Cyclades to the west. This complex, which includes 27 inhabited and countless uninhabited islands and covers a total land area of 2714 square kilometers, is intricately linked to the historical and cultural tapestry of the larger Southern Sporades region. The term "Dodecanese" first appeared in Byzantine records in the eighth century, referring to the twelve islands around Delos in the Cyclades, not the current constellation of islands with the same name. However, current usage has consolidated "Dodecanese" to comprise a chosen ensemble of twelve important islands, notably including Kalymnos, Symi, Leros, Icaria, Patmos, Astypalea, Nisyros, Halki, Tilos, Karpathos, Kasos, and Kastellorizo.

The physiogeography of the Dodecanese presents a diverse mosaic across its islands. Characterized by infertile and rocky terrains, 42% of the Dodecanese total area is flat, while 26% slopes gently and 32% is mountainous. The region is notably devoid of rivers; however, it does have intermittent running waters and streams. The Dodecanese is famous for its volcanic activity, which provides enormous mineral resources. Climatically, the islands experience mild winters and cool summers, earning the region its reputation as the sunniest corner of Greece.

Each island in the Dodecanese has a distinct economic landscape. Predominantly agrarian, the larger islands maintain ongoing agricultural activity, with a considerable fraction of the local population engaged in sponge fishing, which is especially prevalent along Kalymnos' coast. Tourism is a pillar of the Dodecanese economy, attracting visitors to its stunning landscapes and cultural heritage.

The Dodecanese archipelago is situated in the southeastern section of the Hellenic arc, where the two lithospheric plates, the European and the African, converge. This area is known for its intricate geotectonic structure, as illustrated in **Figure 12**. To the north, there are metamorphic rocks originating from Turkey's Menderes Mountain range, which extend partially onto the mainland and then continue southwestward, connecting with the Paleozoic metamorphic foundation of islands such as Patmos, Leros, Kalymnos, and Kos. Above these rocks, there are limestone formations and ophiolites that formed during the Alpine orogeny. These rocks resulted from the fracturing of the continental crust and the adjacent seafloor. On the Greek side, these mixtures of crushed rocks, referred to as "nappes," are categorized as components of the Pelagonian and Sub-Pelagonian zones, whereas in Turkish literature, they are termed "Lycian nappes" (**Higgins & Higgins, 1996**).

Samos is strategically placed near Ikaria and Chios, with the Turkish shore just beyond the Mykale Strait, which is only three kilometers wide. The island spans around 475 square kilometers and has a 159-kilometer shoreline. The quaint town of Vathy serves as Samos' capital, located along the island's northeastern coast and home to around 40,000 inhabitants.

Samos' scenery is crisscrossed by flowing brooks that flow from the Ambelos mountain ranges. The ground is dotted with two small artificially created lakes made by natural springs toward the east. Mount Kerkis, which is also known as Kerketeus, is Samos' and the Aegean's highest summit. Its peaks, Vigla at 1450 metres and Zestane at 1195 metres, dominate the island's skyline.

Samos' terrain is known for its green woods and fertile valleys. Delicate plains and beautiful valleys intersperse the rough mountains, which are primarily covered in olive gardens, citrus orchards, and orange trees. The island's landscape is covered in a stunning tapestry of flora, including bushes, pine woods, plane trees, cypresses, and chestnut trees. Additionally, Samos is famous for its viticulture, with numerous vineyards dotting the landscape, producing renowned and superb wines that are deeply embedded in the island's cultural heritage. Mount Kerkis is a haven for numerous avian species, while Samos' coastal seas are swarming with seagulls and, on occasion, flamingos.

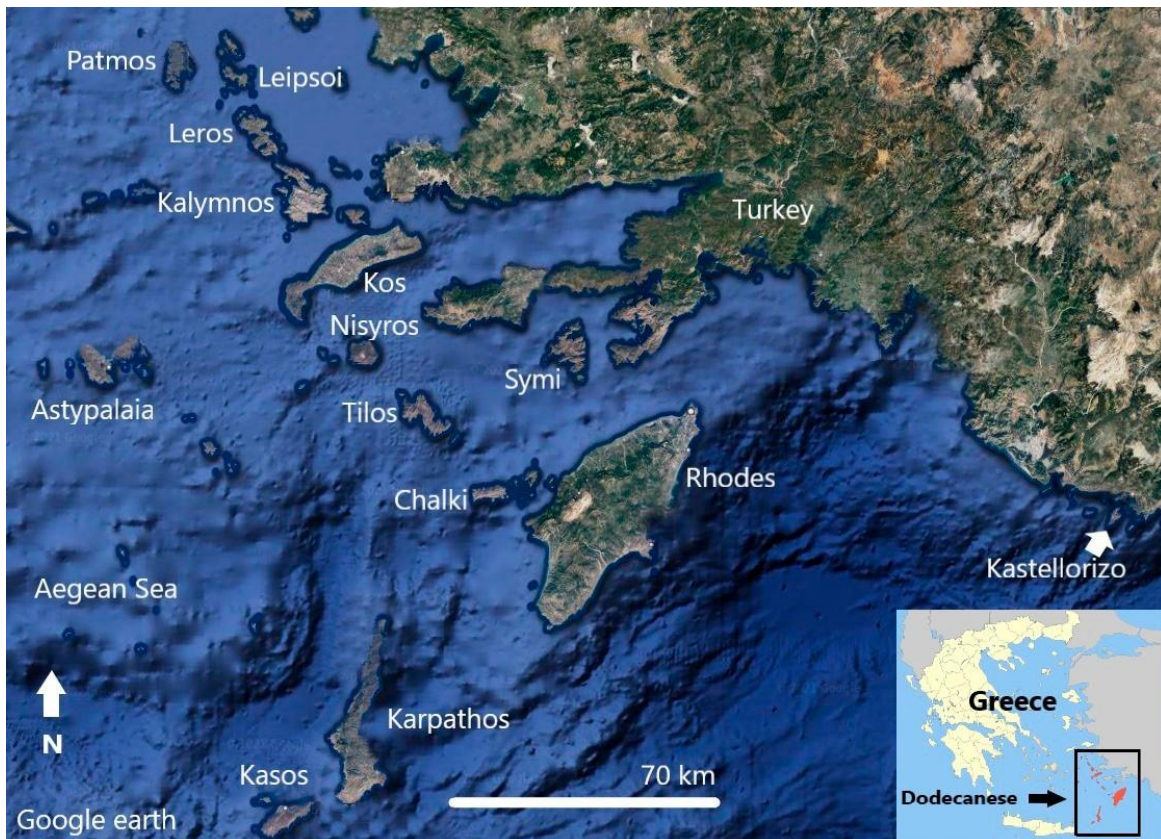
### 4.3. The island of Kalymnos

Kalymnos is part of the Dodecanese Island Complex (**Figure 12**), in the southeast Aegean Sea, covering an area of 109 square kilometers (equivalent to 42 square miles), with a population

of about 12,000 inhabitants, which are mostly leaving in the capital and main port, Pothia. Furthermore, on the north side, a peninsula reaches northwestward. Kalymnos is largely mountainous, with a complex geography.

Kalymnos is well-known for its large sponge fishing industry, which has employed a significant portion of the island's elderly population. However, the once-thriving industry suffered a major fall in 1986 when Mediterranean sponges succumbed to a terrible viral illness, resulting in a significant reduction in their number. As a result, the island's economy experienced a significant setback, like the fate of its famed industry.

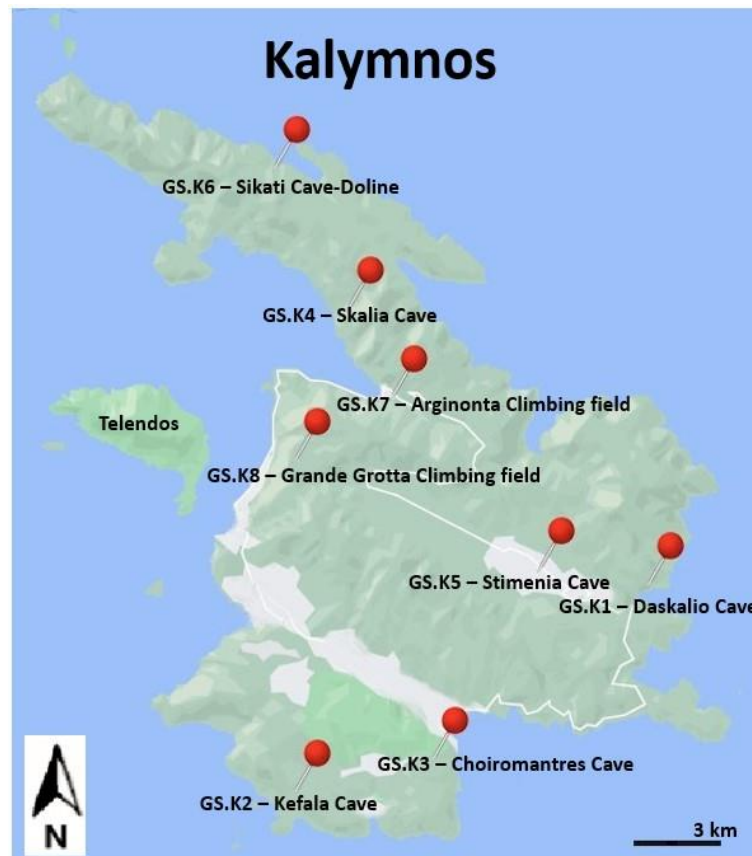
Nowadays, Kalymnos has emerged as a burgeoning holiday destination, thanks to its rugged landscape and geology, which provide optimal conditions for rock climbing. This transformation has ushered in a new era of active tourism on the island. Adventurous travelers are drawn to Kalymnos to explore its rocky mountains and captivating caves, with the Cave of the Seven Virgins standing out as a particularly renowned attraction. The influx of tourists has provided a much-needed boost to the island's economy and its residents, although many of its pristine coastlines remain uncrowded even during peak seasons.



**Figure 12.** Satellite photo of the Dodecanese Island complex, SE Greece; Inlet: Sketch map of Greece indicating the location of Dodecanese island complex

Telendos Island, situated directly opposite Kalymnos, was once part of the same landmass until a seismic event in the 6th century A.D. resulted in its separation. Despite this geological division, Telendos remains administratively part of Kalymnos.

The small island of Telendos, located off the northwestern coast of Kalymnos (depicted in **Figure 13**), is separated from the main island by a 700-meter-wide strait. Telendos used to be connected to Kalymnos until a significant earthquake in the year 535 A.D. caused it to become detached from the larger island. This event led to the formation of the prominent mountain that now commands the scenery on this side of Kalymnos. Telendos is characterized by its non-profit line and uninhabited nature (**Koutellas, 2005; Volonakis, 1982; Simpson & Lazenby, 1973**).



**Figure 13.** Satellite map of Kalymnos Island indicating the caves and climbing fields of the study area

#### 4.3.1. Geology-Geomorphology of Kalymnos

There have been very limited research publications concerning the geological aspects of Kalymnos Island. From a geological perspective, the island is considered part of the external Hellenides. When examining lithologies and the pre-Alpidic metamorphic history, it has been proposed that the pre-Alpidic basement rocks on Kalymnos Island exhibit significant similarities to those found in Eastern Crete. These lithotectonic units underwent greenschist to amphibolite

facies conditions during the Variscan orogeny. In contrast to the rocks in Eastern Crete, which display a high-pressure Alpine alteration, the Variscan basement units on Kalymnos Island do not exhibit significant or exhibit only minor levels of Alpine metamorphism (**Chatziioannou et al., 2015**).

The crystalline rocks, believed to date back to the Variscan era (**Katagas & Sapountzis, 1977; Katagas, 1980; Dürr & Jacobshagen, 1986**), are exposed in extensive sections. **Katagas & Sapountzis (1977)** identified four tectono-metamorphic units, while **Franz et al., (2005)** later condensed them into two main units: the upper Marina unit and the lower Temenia unit. These units are overlaid by a sedimentary layer attributed to the Miocene period. The Marina unit comprises amphibolites and garnet-micaschists (representing the pre-Alpidic basement) along with a relatively low-grade metamorphic sedimentary cover consisting of Permo-Triassic metapelites, metasandstones, and Jurassic marbles. These are structurally underlain by the Temenia Unit (**Dürr, 1975**), which includes late Palaeozoic to Mesozoic sediments that have undergone Alpidic high-pressure metamorphism (**Dürr, 1975**). According to **Dürr (1986)** and **Dürr et al., (1978)**, the crystalline rocks form the foundational component of the Marina Unit and are sequentially overlaid by siliciclastic "Verrucano" sediments (possibly of Permo-Triassic origin). These sediments transition into dolomite and limestone (Upper Triassic to Liassic) and then into well-layered limestone with replacement chert (potentially from the Upper Jurassic to Lower Cretaceous period). Both the Temenia Unit (**Figure 14**) and the sedimentary formations in the Marina Unit share lithological similarities with units found in the Lycian Taurus region in southwestern Turkey (**Dürr et al., 1978**).

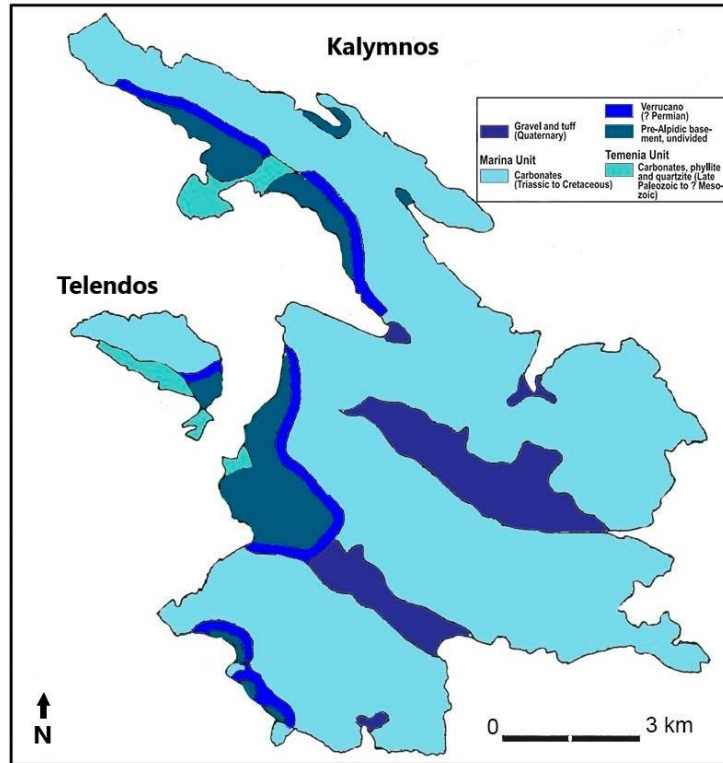


Figure 14. The geology of Kalymnos island according to Franz et al., 2005 (modified by us)

According to **Mimides et al., 2007**, Kalymnos can be stratigraphically divided into the following units (as shown in **Figure 15**):

**Paleozoic Unit:** This is the oldest unit, and its lowermost sections consist mainly of thick-bedded white and dolomite limestones. Moving upwards, it transitions to dark, thickly bedded and thinly bedded limestones, and in its upper parts, it comprises shale, phyllite, and clay schists interspersed with layers of limestone.

**Tectonic Unit of Amphibolites, Schists, and Gneisses:** In this unit, amphibolites are found in narrow layers amid schists and gneisses. These rocks exhibit a range of grain sizes, including fine-grained, medium-grained, and coarse-grained types, and they date back to the Upper Carboniferous period.

**Tectonic Unit of the Ionian Zone:** This unit consists of sub-units, detailed below:

- i. Clastic base formations of the upper Permian: These formations serve as the foundation of the Ionian zone and comprise fine-grained to coarse-grained sandstones, conglomerates, metashales, clay schists, and micritic and breccial limestones.
- ii. Triassic dolomites and dolomite limestones: These mark a typical transition from the clastic base formation.

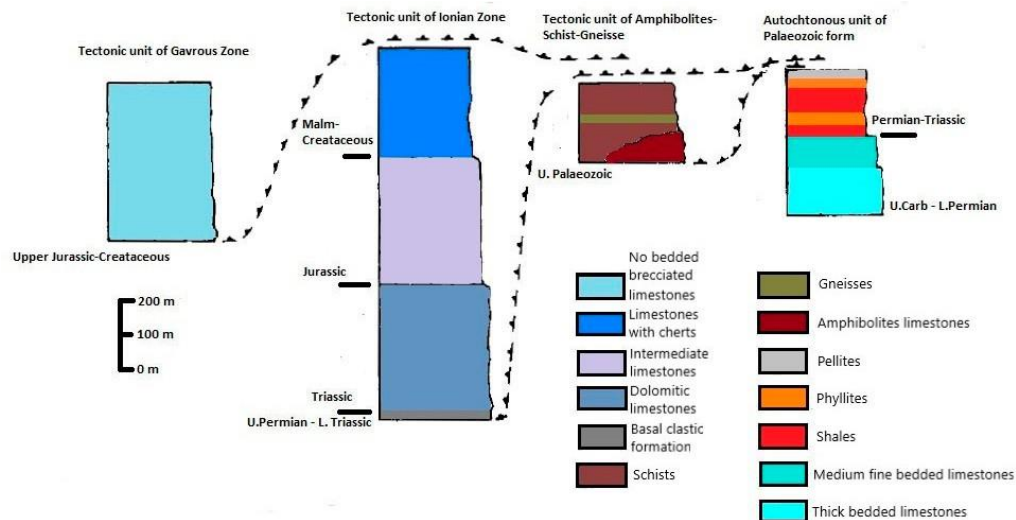
- iii. Middle limestones: These are the characteristic upper layers of the Triassic dolomites and dolomite limestones, with bituminous components in the lower parts.
- iv. Malmian-Cretaceous upper and middle cherty limestones.

**Tectonic Unit of the Gavrovo Zone:** This unit, which dates to the Upper Jurassic-Cretaceous period, is primarily represented by thick limestone deposits.

**Neogene Formations:** These formations are distributed across various locations on the island, covering relatively small areas. They consist of white marls, yellow-red clays, clay-marls with gray to gray-yellow hues, white marl limestones, brown-gray, and gray-layered conglomerates of varying thickness, along with conglomerates containing argillaceous-marly matrix. These Neogene formations are of limnic origin and may date to the Pliocene period.

**Quaternary Formations:** These formations encompass the following layers:

- i. Pleistocene formations, which include consolidated slide rocks, fan conglomerates, volcanic tuffs, and a volcanic pyroclastic formation primarily composed of rhyolite.
- ii. Holocene formations, comprising talus slope screens, detrital cones, alluvial valley deposits with terra rossa, and coastal sands.



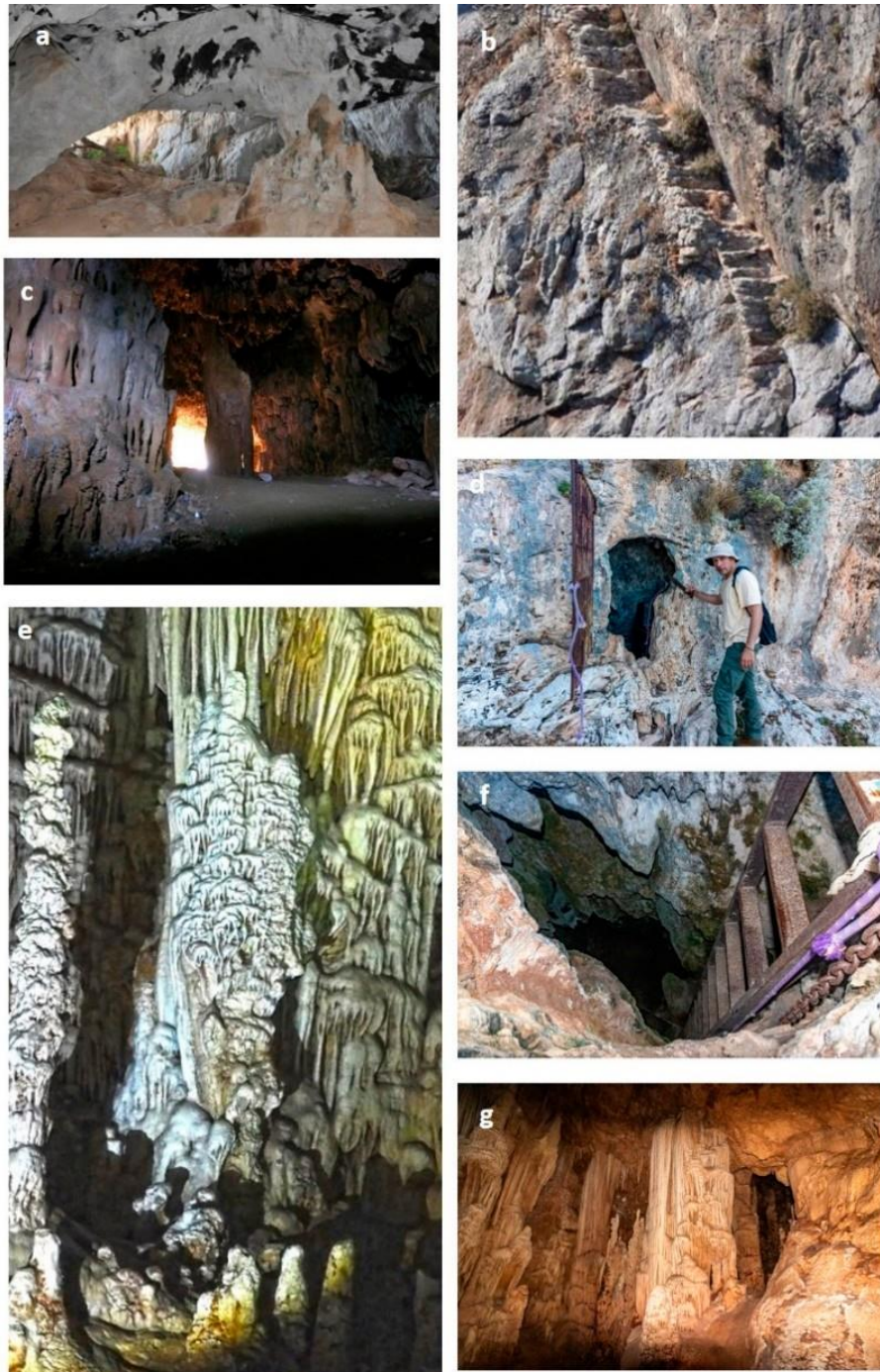
**Figure 15.** The stratigraphy of Kalymnos according to Mimides et al., 2007 (modified)

In terms of its geomorphology, Kalymnos displays an irregular shape with a predominantly mountainous terrain. It can be described as a semi-mountainous to mountainous island, characterized by significant horizontal and vertical variations resulting from tectonic forces. The island comprises three roughly parallel mountain ranges that extend from the sea, running approximately in a west-northwest to east-southeast direction. Among these three ranges, the middle one is the highest and is flanked by valleys to the north and south. The northernmost range, on the other hand, takes the form of an elongated peninsula projecting northwestward, featuring

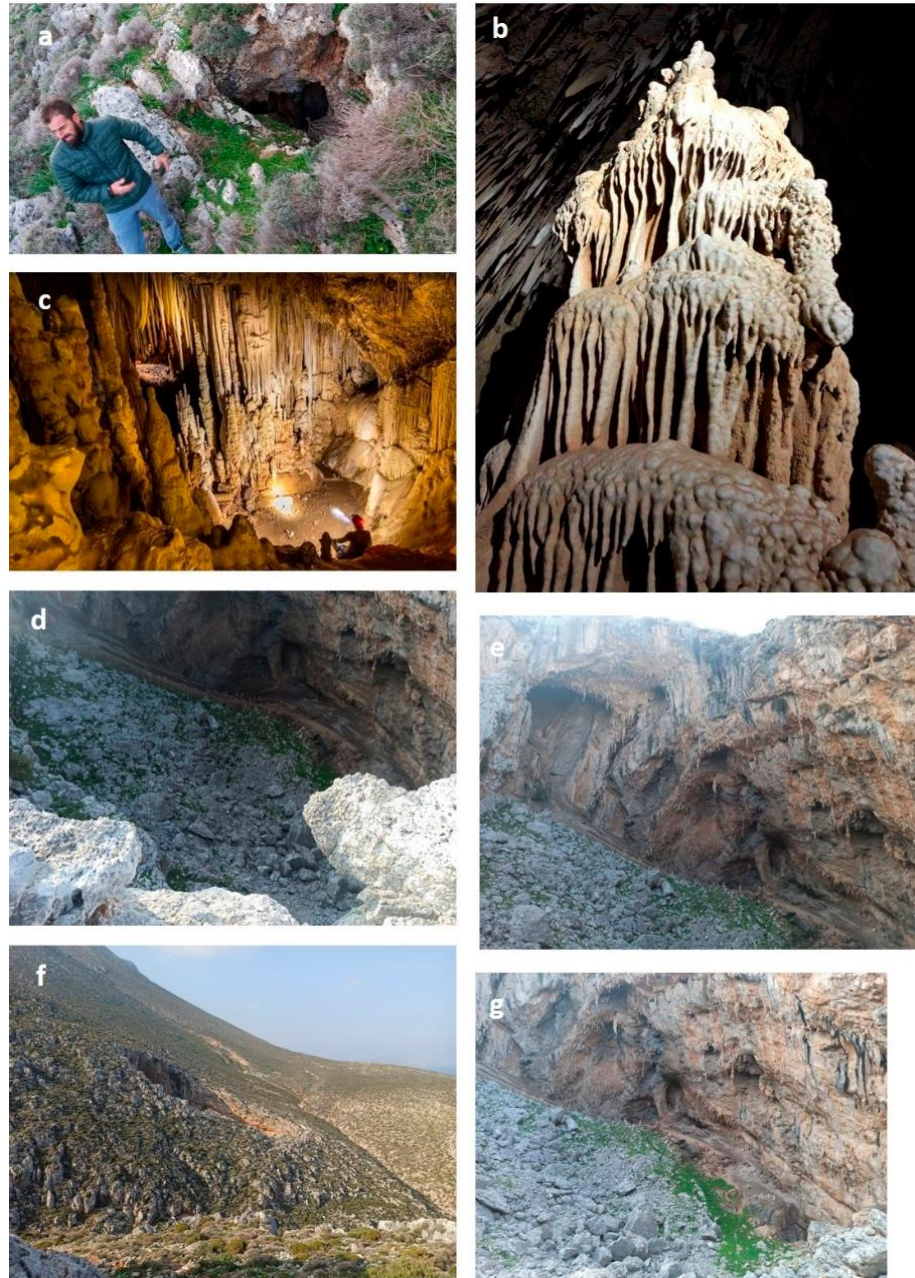
steep slopes along its entire length. Kalymnos is marked by the presence of numerous deep ravines and mountains throughout its terrain. The highest peak on the island is Profitis Ilias, which stands at an elevation of 678 meters and is in the central region. The island can be divided into two main parts: the northern part, where an orographic axis-oriented NNW-SSE prevails, and the southern part, where three parallel NNW-SSE orographic axes are prominent. Notably, the only low-lying areas, constituting less than 10% of the total land area, are situated at the mouths of the primary watercourses in the Panormos and Vathys regions (as depicted in **Figure 14**).

#### 4.3.2. The geological monuments of Kalymnos

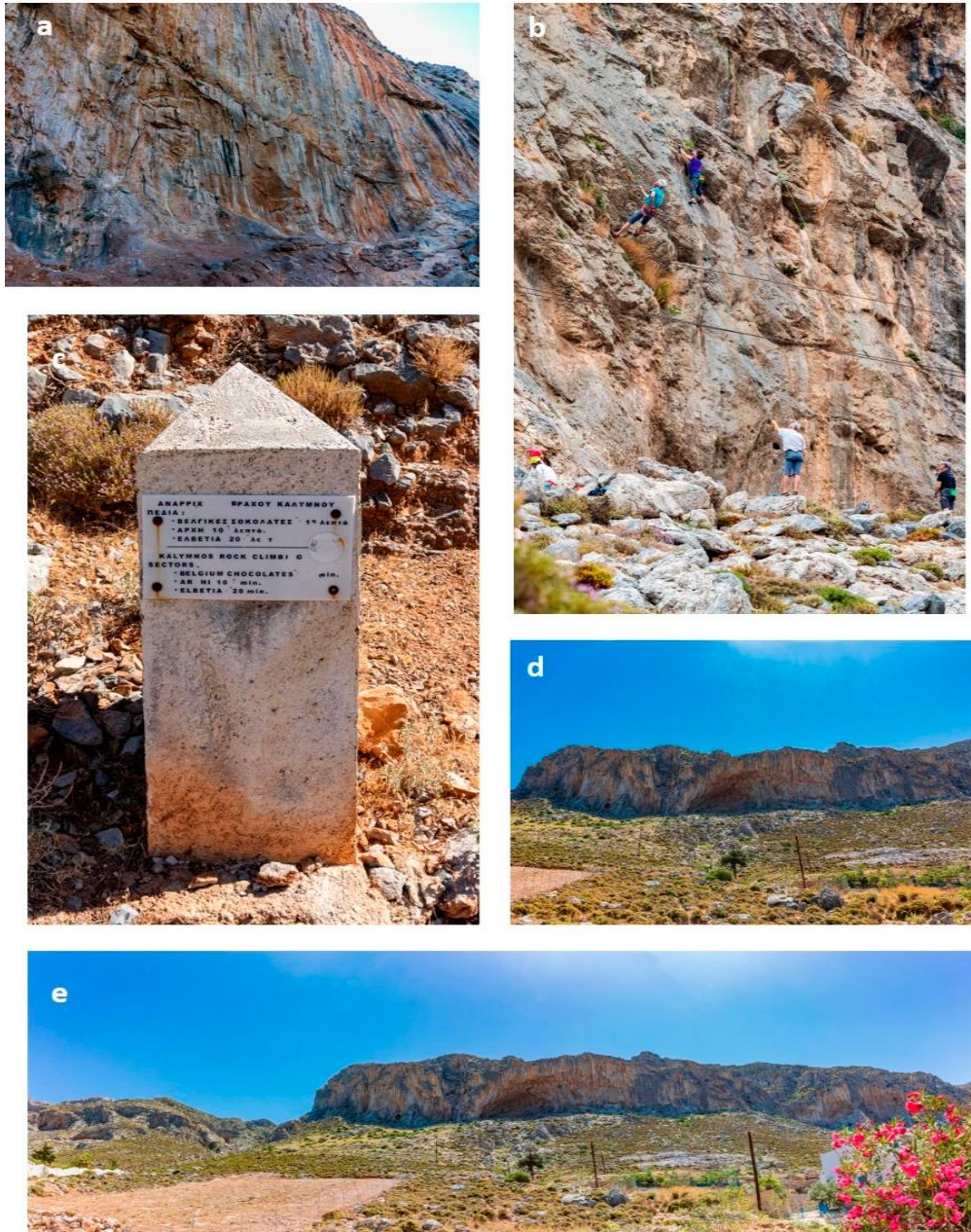
The studied geological monuments in Kalymnos Island consist of six caves (Daskalio, Kefala, Choiromantres, Skalia, Stimenia, and Sikati caves) and two climbing areas (Arginonta and Grande Grotta) (as shown in **Figure 13** and **Figure 16-Figure 18**). It's important to mention that not all these geological monuments have undergone a comprehensive study, description, or documentation. Consequently, the descriptions for some of these geosites are relatively brief due to lack of data.



**Figure 16.** (a) Interior of Daskalio cave (GS.K1); (b) the stairs leading to the Daskalio cave (GS.K1); (c) interior of Kefala cave (GS.K2); (d) the entrance of Skalia cave (GS.K4); (e) stalagmites in Skalia Cave (GS.K4); (f) the first staircase to descend to the interior of the Skalia cave (GS.K4); (g) interior of Skalia cave (GS.K4)



**Figure 17.** (a) The entrance of Stimenia cave (GS.K5); (b) interior of Stimenia cave (GS.K5); (c) a part of the main chamber of the cave Stimenia (GS.K5); (d) at the entrance of the cave-doline Sikati (GS.K6); (e) in the middle of the Sikati doline (GS.K6); (f) external view of Sikati doline (GS.K6); (g) on the right side of Sikati doline (GS.K6)



**Figure 18.** (a) Climbing field with the name Archi, in the area of Arginonta (GS.K7); (b) outside of the village Arginonta, the climbers at action; (c) a typical information column for climbers, which lists the exact name of a particular climbing route and the time of its approach; (d) the famous climbing field Grande Grotta (GS.K8); (e) the Grande Grotta climbing field and the wider area

**GS.K1—Daskalio cave (Figure 13 and Figure 16a,b)**, is situated in proximity to the Vathys port, along the northern edge of the small, fjord-like bay of Rina, at an elevation of around 12 meters above sea level. It can only be accessed from the sea, and a set of ancient stairs, dating back to the Byzantine era, offers a rather poorly preserved means of entry. Upon entering, one is led directly into the main chamber, which stretches 25 meters in length and widens to 12 meters at its broadest point. The ceiling reaches a height of 10 meters. Gradually, the floor slopes downward into a secondary chamber on the eastern side, where enormous stalagmites can be found (**Maiuri,**

1928). From the lower chamber, there is a steep descent into a sizable cavity where water has collected. Although the pond is now tainted with seawater, it was once a source of potable water that dripped from the ceiling. Through archaeological excavations, a trove of valuable artifacts has been unearthed, revealing that human activity in the cave dates to the late Neolithic period and persisted throughout the Bronze Age, encompassing the Early, Middle, and Late phases, as well as the Geometric era. Daskalio cave stands out as possessing the most extensive assortment of relics from this time frame. Among the discoveries are numerous Minoan and Mycenaean pottery vessels. Additionally, the cave's location appears to have held significance for religious or ceremonial purposes, as indicated by the finding of ritualistic objects and a bronze figurine representing a praying figure.

**GS.K2—Kefala Cave**, also known as the Cave of Zeus, (**Figure 19 and Figure 16c**), is situated on the western side of Mount Karina, at the southwestern edge of Kalymnos Island, near Cape Kefalas. It's approximately 2 kilometers southwest of Vothynoi. This cave is widely regarded as the most stunning and remarkable cave on the entire island, covering an area of 1000 square meters and featuring six inner chambers. The cave's most notable feature is its impressive 103-meter-long corridor adorned with enormous stalactites and stalagmites. Its entrance is found at an elevation of 105 meters above sea level. Inside, there's a spacious hall with maximum dimensions of approximately 40 by 25 meters, which is subdivided into smaller chambers by groups of stalagmite and stalactite formations. Beyond the entrance, the first hall is relatively small with a low ceiling. A tunnel with a steep incline branches off from the left side of this hall, leading to the primary chamber, which has maximum measurements of roughly 9 by 20 by 6 meters and a sloping floor. Three smaller chambers can be accessed through small openings in the walls of the main hall. Notably, there are signs of worship associated with Olympian Zeus within the cave, hence its alternate name, the 'Cave of Zeus.' Officially discovered in 1960, it was initially explored in 1961, mapped by a mission from the Hellenic Speleological Society in 1977, and in 2004, it became one of the first caves in Greece to have a topographic plan created using a laser scanner (**Tsakiri et al., 2007**). Access to the cave can be achieved either by following a path from the Abbey of Saint Aikaterini in Vothynoi or by taking a sea route from the harbor of Pothia using small boats that offer daily marine excursions to the cave.

**GS.K3—Choiromantres Cave** is situated on the southern slope of Pothia, situated beneath the Agioi Pantas monastery (All Saints). Regrettably, the cave's original shape was altered due to the collapse of its dome. Presently, the pit measures 12 meters in width and has a depth ranging from 3 to 5.5 meters.

In 1921, Italian archaeologist A. Maiuri conducted an excavation at a section near the cave's entrance, reaching depths of 4 to 4.5 meters. During this excavation, a variety of artifacts from the Neolithic period and shells dating back to the early Christian era were unearthed both within the cave and its vicinity. The presence of these artifacts provides evidence of continuous human occupation and ritual use of the site over time. It's worth noting that the exact timing and reasons for the collapse of the cave's canopy remain unknown.

**GS.K4—Skalia Cave**, also known as the Cave of Agios Ioannis, is located in Massouri, approximately one kilometer away from Skalia, (**Figure 13 and Figure 16d,g**). This cave was carved into Jurassic dolomitized limestone through erosion processes. It stretches in a straight line from WNW to ESE, covering 60 meters and reaching a maximum depth of 32 meters. The cave encompasses an area of 1500 square meters, with the tourist route spanning approximately 250 meters. In May, the cave's internal temperature hovers around 25 degrees Celsius, while its humidity levels reach up to 98%. Skalia Cave is renowned for its awe-inspiring natural adornments, featuring peculiar formations of stalactites. From a tourism perspective, it is considered a remarkable destination of international significance, primarily due to its abundant and impressive decorations, including exceptionally tall columns and intricate stalagmite complexes. Within the cave, you can observe stalagmites resembling masts and candles, with diameters ranging from 0.05 to 0.10 meters and reaching heights of up to 6 meters (**Petrochilou, 1989**).

**GS.K5—Stimienia Cave**, (**Figure 13 and Figure 17a,c**), is found in the northeastern region of the Vathy valley, specifically in the vicinity of Ai Nikolas. Not far from this location, towards the northwest of the valley, two more caves exist, and archaeological findings indicate their historical use as dwellings in ancient times. Stimienia Cave features openings in its ceiling that serve dual purposes: providing natural light to the cave's interior and serving as entry points for people. The cave's interior decorations are exceptionally impressive. In the surrounding area, one can come across remnants of early Christian and Byzantine ceramics, ancient stone tools, and the remains of structures from bygone eras.

**GS.K6—Sikati Doline**,(**Figure 13 and Figure 17d,g**), is found on the northeastern shoreline of Kalymnos. While rock climbers often know it as Sikati, locals commonly refer to it as Alatsia. This feature resembles an enormous depression in the ground, essentially a cavern without an overhead covering. It spans a diameter of 50 to 60 meters and, in some areas, plunges to depths of up to 70 meters.

**GS.K7—Arginonta climbing field**, (**Figure 13 and Figure 18a,c**), is situated on the northwestern part of Kalymnos, approximately 16.5 kilometers away from Pothia. It comprises a cluster of three cliffs that can be reached within a short stroll from the parking area in the village of Arginonta.

**GS.K8—Grande Grotta climbing field** (**Figure 13 and Figure 18d,e**) is one of the most beautiful landscapes of the island of Kalymnos and the most must-see destination for the self-respecting rock climber! The Grande Grotta cave of Kalymnos forms a huge limestone amphitheater. It is 70 m high and 200 m wide, with huge stalactites and stunning views. It is an attraction for thousands of climbers from all over the world, as it offers unforgettable experiences.

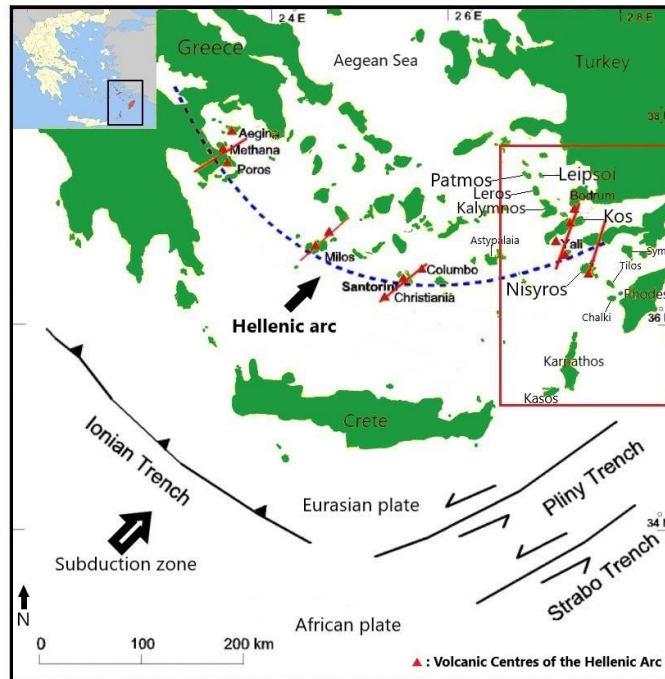
#### 4.4. The island of Nisyros

Nisyros Island, located within the Dodecanese Island Complex, constitutes one of the most recent volcanic formations within the tectonically active South Aegean Active Volcanic Arc. This volcanic arc owes its existence to the subduction of lithospheric plates from the Eastern Mediterranean beneath the dynamic Hellenic margin of the European plate. Positioned within the broader geological framework of the Kos–Yali–Nisyros Volcanic Field, Nisyros occupies a pivotal location on the eastern fringes of the volcanic island arc within the South Aegean region (**Figure 19 and Figure 20**) (**Dietrich & Lagios, 2018**).

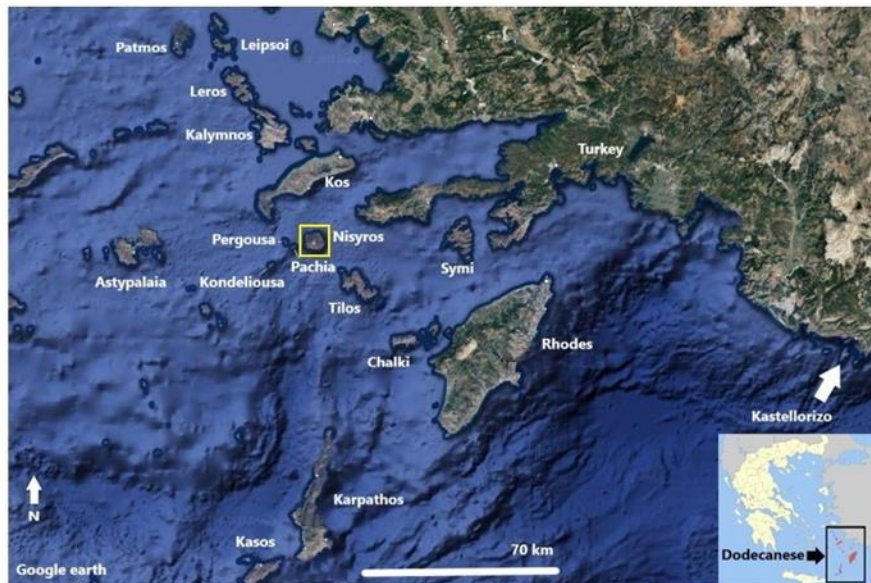
Situated between the islands of Kos and Tilos, Nisyros resides within a prehistoric volcanic field that experienced a monumental volcanic eruption 161,000 years ago, known as the Kos Plateau Tuff eruption, which significantly impacted the entire Dodecanese area. The island's volcanic features have bestowed upon it rich, nutrient-laden soil, fostering lush herbaceous vegetation year-round and providing habitat to a diverse array of flora and fauna. Additionally, Nisyros boasts several thermal springs at sea level, aligned along major fault zones, which have been utilized for their therapeutic benefits since ancient times.

The northern and eastern slopes of the Nisyros volcano, along with its neighboring island Yali, are adorned with extensive deposits of pumice, actively mined on a large scale. While efforts were made to harness the geothermal energy potential of the active hydrothermal system on the southern part of the caldera floor, these initiatives were abandoned due to high-risk factors and ongoing micro-seismic activity. Notably, seismic activity in 1996 and 1997, including earthquakes of magnitudes up to 5.5 and hypocenters reaching depths of 10 km, caused significant damage to numerous homes in the major town of Mandraki.

In contemporary times, tourism has emerged as the primary economic drive of Nisyros. Hundreds of visitors flock to the island daily to marvel at the impressive hydrothermal explosion craters on the caldera floor, lured by the sight of fuming fumaroles and bubbling mud pools, which serve as captivating reminders of Nisyros's dynamic volcanic heritage.



**Figure 19.** Location of the Dodecanese complex in the southeastern branch of the South Aegean Active Volcanic Arc, at the convergence limits of the two lithospheric plates, the Eurasian and the African

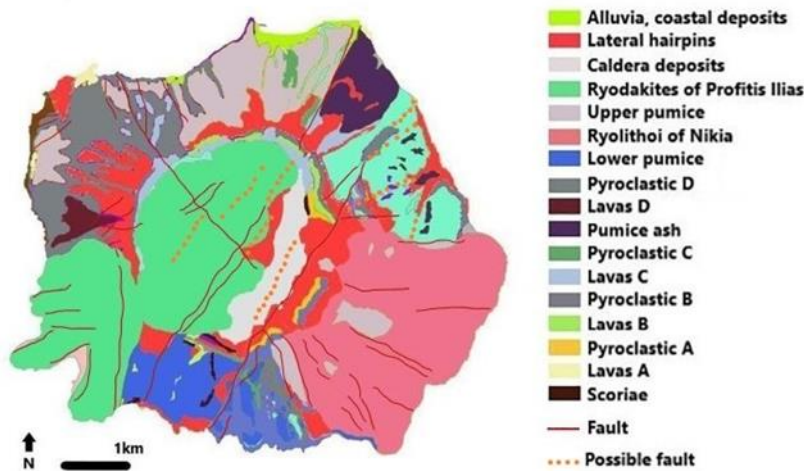


**Figure 20.** Satellite photo of the Dodecanese island complex, SE Greece, indicating the location of Nisyros Island; Inlet: Sketch map of Greece indicating the location of Dodecanese island complex

#### 4.4.1. Geology-Geomorphology of Nisyros

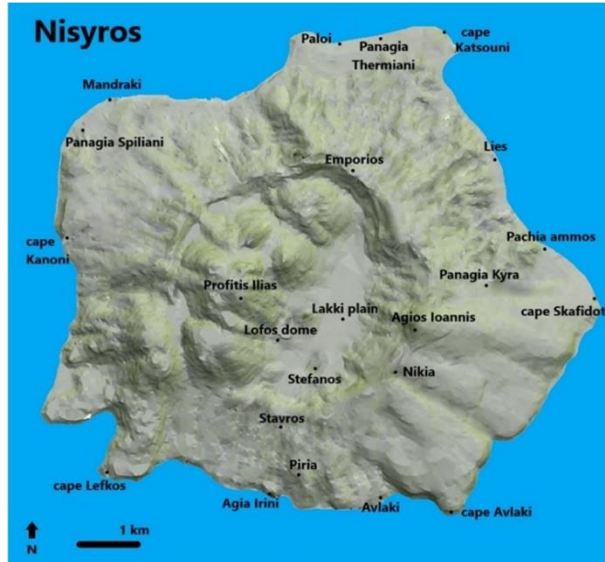
An ENE-WSW trending neotectonic graben on Nisyros has a stratovolcano-like structure that dates back to the Late Pleistocene and Early Holocene (**Papanikolaou et al., 1991; Tibaldi et al., 2008**). The stratigraphy of this region is characterized by the intercalations of andesitic lavas

with andesitic pyroclastic deposits joined by feeder systems of sills and dykes of a similar composition, which can be observed in the cores of geothermal energy test drillholes (**Figure 21**). Rhyodacitic post-caldera domes are the highest point of the exposed strata, which starts with pillowed basaltic andesite and pillow breccia and advances to greater felsic volcanism (**Papanikolaou et al., 1991; Francalanci et al., 2005**).



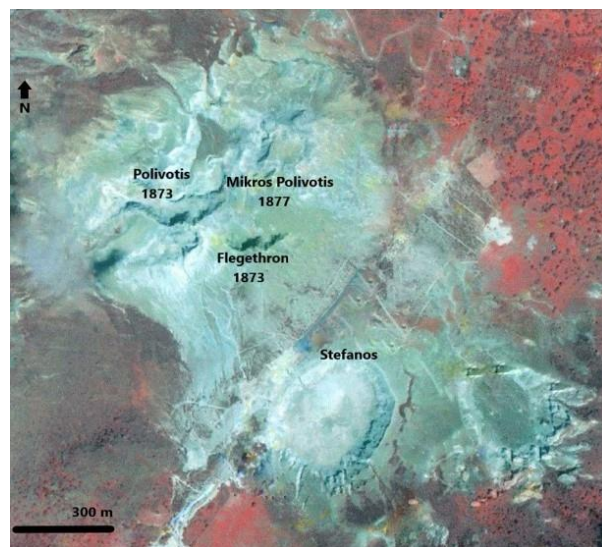
**Figure 21.** Geological map of Nisyros (Papanikolaou et al., 1991), modified

The current shape of the caldera is easily recognizable as a circular topographical feature measuring 4 kilometers in diameter. Within the caldera, there is a flat floor, and it contains phreatic craters with cliffs that reach heights of up to 300 meters **Dietrich & Lagios, 2018**. The summit of Profitis Ilias (**Figure 22**) forms the highest point within this post-caldera dome, standing at an elevation of 698 meters (**Papanikolaou et al., 1991; Khaleghi et al., 2020; Rajan Girija & Mayappan, 2019; Di Paola, 1974; Hunziker & Marini, 2005**). The geological stratigraphy exposed in this area dates back approximately 160,000 years, and the most recent phreatic eruption took place in the year 1867 A.D. (**Martelli, 1917**).



**Figure 22.** 3D representation of the surface of Nisyros Island, indicating the location of places referred in the text (Marini & Fiebig, 2005), modified

Within the caldera, there is a renowned hydrothermal-fumarolic field characterized by its hydrothermal activity. This activity is evident on the surface through a network of intersecting hydrothermal craters, primarily situated in the southern part of the Lakki plain (**Figure 22**). These craters are influenced by diffuse degassing structures. Among the most notable hydrothermal craters in this area are Stefanos, Phlegethon, Megalos Polyvotis, and Mikros Polyvotis (**Figure 23**). Notably, the most recent crater, "Mikros Polyvotis," was formed in 1887 as a result of the volcano's most recent hydrothermal explosion (Papanikolaou et al., 1991; Ambrosio et al., 2010; Gorceix, 1873a; Gorceix, 1873b; Gorceix, 1874; Marini et al., 1993).



**Figure 23.** Satellite photo of the craters (Vassilopoulou & Hurni, 2001), modified

The Nisyros caldera is of special interest due to the existence of epithermal gold, with concentrations of 82 parts per billion (ppb) in the Lofos dome area and notably higher concentrations of 2500 ppb in the nearby Profitis Ilias area. These findings suggest the occurrence of substantial hydrothermal circulation phenomena (**Marini et al., 1993**).

Numerous researchers have examined the development of Nisyros Volcano spanning the past 160,000 years, along with the sequence of calc-alkaline lavas and pyroclastic rocks. Initial geological investigations of Nisyros Island were performed by Italian geologists **Martelli (1917)** and **Desio (1931)**. In-depth geological inquiries commenced in the late 1960s (**Davis, 1967**) and were continued by **Di Paola (1974)** and **Papanikolaou et al., (1991)**. Their findings delineate the volcanic history of the island into five distinct stages:

- i. Initially, the lower volcanic formations observed along the northern coast near Mandraki were shaped by an underwater volcano that discharged basaltic and andesitic pillow-lavas.
- ii. Over a span of more than 100,000 years, a stratovolcano reaching heights of 500–700 meters evolved above these partially submerged lavas.
- iii. Following numerous phases of eruptive gas and steam events, two significant rhyodacitic plinian eruptions blanketed the entire island with pyroclastic flows and pumice falls.
- iv. Around 20,000 years ago, a substantial central vertical collapse of the volcano occurred, resulting in the formation of a large caldera.
- v. During prehistoric periods, the western region of the caldera depression was filled by a sequence of rhyodacitic domes, with the highest one, Profitis Ilias, reaching an elevation of 698 meters above sea level.

For a minimum of 25,000 years, there has been no recorded volcanic activity on the island since the establishment of the domes. The sole documented historical eruptions are linked to the creation of various phreatic craters within the caldera, including Alexandros, Polyvotis, Stephanos, Phlegethon, and Achelous, which continue to emit fumaroles. The most recent hydrothermal eruptions took place in 1871–1873 and 1887 AD, and they were characterized by intense earthquakes, gas explosions, steam outbursts, and mudflows (**Marini et al., 1993**).

The primary distinction in the volcanic history of Nisyros is the initial phase when the stratovolcano developed and concluded with a significant eruption (Nikia rhyolites) and the formation of a caldera. This was succeeded by the second phase characterized by the formation of volcanic domes, which altered the previous caldera rim (now located at approximately 300 meters elevation) and led to the creation of the highest peak, Profitis Ilias, reaching 698 meters. Recent volcanic activities beneath the waters surrounding Nisyros have given rise to the volcanic centers of Pergousa, Yali, Strongyli, Pachia, and Kondelioussa (**Figure 24**) (**Piper et al., 2019; Papanikolaou & Nomikou, 2001**).

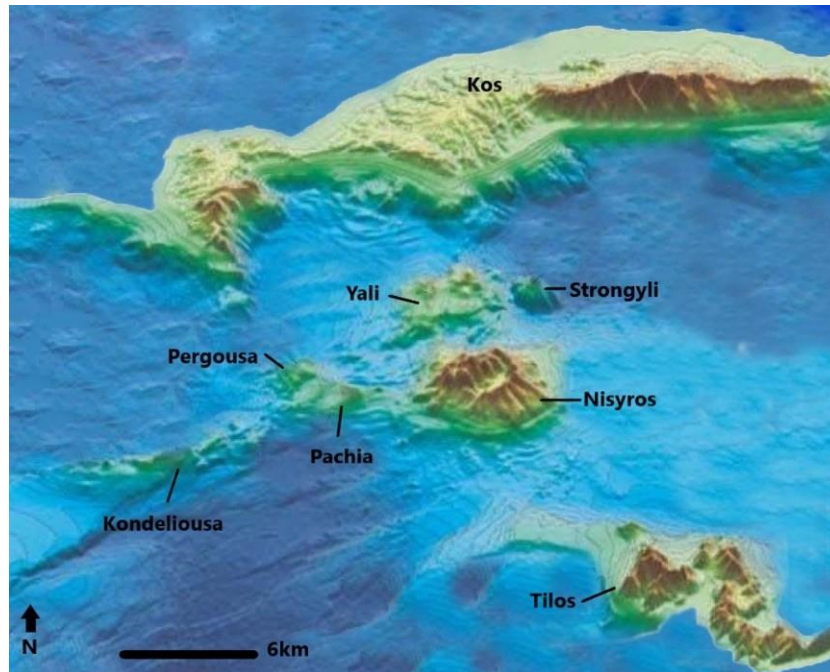


Figure 24. Nisyros and the other smaller island around (Lagios et al., 2005), modified

Following a period of dormancy, a substantial increase in seismic activity commenced towards the end of 1995 and continued until 1998, with the most notable seismic event occurring on 27 August 1997, registering a magnitude of 5.3. This heightened seismic activity led to notable alterations in the geochemical parameters of fumaroles, progressive elevation changes, and east-west stretching in the central regions of the island, along with indications of potential magma influx at greater depths within the Earth's crust (Lagios et al., 2005; Papadopoulos et al., 1998; GEOWARN-IST 12310). This gradual uplift resulted in the formation of a significant north-south-oriented fracture termed the "Lakki rupture" within the Lakki plain of the caldera, which occurred in early December 2001 (GEOWARN-IST 12310).

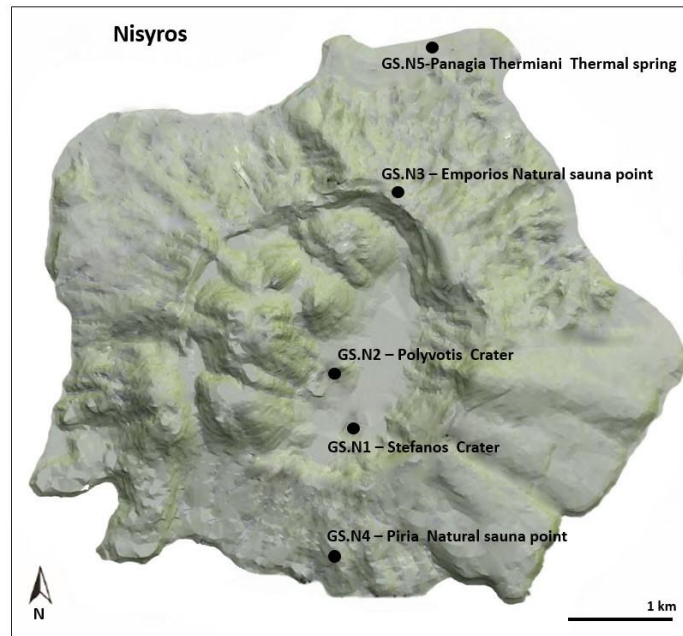
Considering the volcanic activity, there exists a notable hazard within the broader region that poses a potential threat to both inhabitants and tourists. Consequently, the establishment of the Volcanological Observatory of Nisyros has been put in place, equipped with an appropriate monitoring network to oversee the volcano's physical and chemical parameters. This infrastructure enables the reliable forecasting of potential reactivation of the volcano, facilitating the prompt implementation of protective measures.

#### 4.4.2. The geological monuments of Nisyros

Nisyros Island boasts a multitude of captivating geosites, encompassing the expansive volcanic craters of the caldera, thermal springs, and the volcanic islets that encircle it. The island's terrain showcases a diverse array of impressive volcanic features sculpted by natural processes, offering visitors the opportunity to witness the formidable force of volcanoes. All these geosites

are easily accessible and cater to various recreational activities. Furthermore, in addition to the fumarolic activity within the craters, the island exhibits gas emissions along the active tectonic zones intersecting its landscape. There are also thermal springs with temperatures ranging from 27°C to 43°C located near the coastline. Isotopic analysis of thermal water samples from Nisyros indicates a combination of seawater, magmatic water, geothermal steam, and the potential involvement of groundwater and/or meteoric water.

In this research, five specific geosites have been chosen (**Figure 25**). Each of these geosites has been assigned a numerical order and labeled with the letters "GS."



**Figure 25.** 3D representation of Nisyros Island, indicating the location of the studied geosites (Marini et al., 1993), modified

**GS.N1—Stefanos Crater (Figure 26a,b):** Stefanos Crater, elliptical in shape and measuring 260x350 meters, stands out as one of the world's largest phreatic craters. Its unique form seems to have originated from the influence of two primary NE-trending active faults, evidenced by the alignment of fumarolic vents within the crater. The crater reaches a maximum depth of 27 meters. Unfortunately, the precise age of its formation remains unclear. On the eastern walls of Stefanos, seven distinct stratigraphic layers have been identified, including deposits like magmatic lithic talus, epiclastic and fine argillitic layers, fine-grained lacustrine sediments, solid deposits created by the Kaminakia craters' explosive activity, deposits from Stefanos' eruption, and a thin layer of explosive materials from Polyvotis. The immediate vicinity of Stefanos Crater is marked by intense and remarkable geothermal activity, primarily characterized by the release of gases at a temperature of 100 degrees Celsius. These gases consist mainly of water vapor and carbon dioxide, with smaller amounts of hydrogen sulfide, nitrogen, and methane (approximately 0.5%). Notably, amorphous sulfur crystals form at the openings where gas is released, and the vaporized water hydrates the surrounding soil, resulting in the presence of diluted sulfuric acid due

to the dissolution of hydrogen sulfide in the steam. The elliptical shape of Stefanos Crater (260x190 meters) tends to concentrate gases, and consequently, during periods of volcanic activity and intense hydrothermal venting, significant gas emissions occur, often accompanied by seismic events that can trigger landslides (Marini et al., 1993; Sykioti et al., 2003; Venturi et al., 2018; Chiodini et al., 1993).

The distinct and somewhat unpleasant odor in the vicinity is attributed to the presence of hydrogen sulfide, a compound that can be detected by even the smallest concentrations and is noticeable to every visitor.

**GS.N2—Megalos Polyvotis (Figure 26a)** was created as a result of the initial and most forceful hydrothermal explosive event in the Lofos region. It takes the form of an elliptical crater, measuring 180 by 350 meters in dimensions, and is surrounded by a 3-5-meter-thick layer of ejecta. Some of this ejecta is covered by materials originating from Flegethron or Alexandros crater (Figure 29c), a large elliptical-shaped crater located in the southeastern part of the area. This later crater intersects with Megalos Polyvotis. The crater's composition consists of altered lava fragments and rhyodacitic blocks embedded in a clayey-to-sandy matrix. The lava blocks exhibit brown-reddish oxide coatings and are intersected by anhydrite veins. Its stratigraphy is similar to Stefanos, with lacustrine sediments and loose clay material at the base and chaotic ejecta from earlier magmatic events at the top. Following heavy rainfall, the western section of the crater floor often transforms into a lake, consisting of 1.5-meter-thick layers of varved clay in yellow and purple hues, indicating the historical presence of a lake.

GS.N1 and GS.N2 exhibit significant differences in their morphological characteristics. The Stefanos crater (GS.N1) presents a depression in the landscape, while the Polyvotis crater (GS.N2) creates an elevated feature. The elevated nature of Polyvotis is likely attributed to the presence of ridges from nearby post-caldera structures that encircle this crater, combined with materials from previous explosive events. Both Stefanos and Polyvotis craters are primarily composed of clay materials, which limit the infiltration of water into deeper layers, leading to the retention of rainwater and subsequently increasing soil moisture levels. The concurrent vapor activity contributes to the formation of small craters containing hot mud.



**Figure 26.** Geosites of Nisyros Island: (a) the Stefanos (GS.N1) and Polyvotis (GS.N2) craters, (b) the Stefanos crater (GS.N1), (c) the Alexandros crater, (d) the Piria hot spring (GS.N4), (e) natural hot spring of Emporios (GS.N3), and (f) Panagia Thermiani thermal spring (GS.N5).

**GS.N3—Emporios Thermal Spring (Figure 26e):** This thermal spring is situated at the entrance of the Emporios settlement, which is located in the northeastern part of the island. The spring's temperatures range between 36 and 40°C. The presence of this hydrothermal phenomenon can be attributed to the fractured zone in the northeast, which differs from other fault systems on the island (Papanikolaou et al., 1991). Interestingly, it exhibits a divergent direction compared to

the fault systems found on the south, west, and east sides of the island. This unique fault configuration facilitates the movement and circulation of hydrothermal fluids in various instances (Dietrich & Lagios, 2018). Notably, the fault throw created by these faults in certain areas can reach up to 100 meters, further emphasizing the site's strong connection to geothermal activity (Papanikolaou et al., 1991). Consequently, within this small chamber, one can observe the dissipation of heat as well as the presence of sulfur, noticeable as a yellowish appearance on the inner surface of the chamber's surroundings.

**GS.N4—Pyria Thermal Spring** (located in the southern part of the island, as shown in **Figure 26-d**): In 1841, when the German archaeologist Ludwig Ross visited the island from August 9th to 11th, he documented several areas exhibiting hydrothermal activity. Specifically, he noted that in Pyria, also known as the Arodafnes area, there was a noticeable emission of high heat, likely attributed to the extensively fractured southern slopes of the island's caldera. These fractured areas align with the fault zone running in a southwest to northeast direction (Dietrich & Lagios, 2018; Papanikolaou et al., 1991). Originally, there was a complex of stone buildings associated with the thermal spring, featuring 5 to 6 chambers. Today, only one chamber remains intact and in good condition, emitting natural steam with a temperature ranging from 40 to 45°C. The spring continues to be used by both locals and visitors for the same purpose.

**GS.N5—Thermal Spring of Panagia Thermiani**: Situated in the northern region of the island, near the Paloi settlement and adjacent to the small Panagia Thermiani church (as depicted in **Figure 26f**), this water spring has historical significance and has been known since ancient times. Remains of Roman baths have been discovered in this area, providing evidence of its past importance. In 1889, Dr. Pantelis Pantelidis operated a medical facility that utilized the water flowing from this spring. The spring's high salinity may result from the underground movement of water through pyroclastic formations and geological structures that indicate fault zones. Additionally, the spring is influenced by the infiltration of seawater, leading to a mixture of various minerals and meteoric components. This interaction with specific geological formations has contributed to the spring's rich composition, including  $\text{SO}_4^{2-}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ , and  $\text{HCO}_3^-$ . Although the water temperature is a modest 33 degrees Celsius, it is both refreshing and believed to possess healing properties.

This spring is a result of both the geothermal activity on the island and the presence of a ruptured zone in the northern part (Chiodini et al., 1993; Kavouridis et al., 1999; Chiodini et al., 2002; Brombach et al., 2003; Dotsika et al., 2009).

## 4.5. The island of Samos

Samos Island is in the far east-central part of the central Aegean Sea (**Figure 27**), near the Turkish coast, and is separated by the Mykali strait, which is approximately 12 kilometers long and 1200 meters wide (Mc Kenzie, 1970; Mc Kenzie, 1972; Mc Kenzie, 1978). This geological

setup shows that until recently, Samos was physically linked to Western Anatolia (Western Turkey). The island covers an area of 477.2 square kilometers, features a coastline stretching 159 kilometers, and is characterized by unique mountain ranges. Its geological past suggests that it was connected to the Turkish coast during the Pliocene epoch, but geological shifts around 10,000 to 12,500 years ago led to its isolation (**Mc Kenzie, 1972; Mc Kenzie, 1978; Papanikolaou, 1984**). To the northwest of Samos lies a marine basin, exceeding depths of 1000 m, making it one of the deepest marine basins within the Aegean region. Its bathymetric profile suggests a significant normal fault, which governs the coastal morphology along the northwest and west coasts of the island, as noted by **Mascle and Martin (1990)**. Conversely, along the remaining coasts, the bathymetric gradient is much gentler, with depths ranging between 50 to 200 m, indicating a less pronounced topographical relief.

The island of Samos has been extensively investigated in a variety of subjects, providing an abundance of academic papers. Notably, Samos is known for its extraordinary Late Miocene fossil sites containing mammal fauna, a topic explored in studies by **Giaourtsakis & Koufos (2009), Kostopoulos (2009a, 2009b), Koufos (2006), and Koufos et al., (1997, 2011)**.

From a geodynamic point of view, Samos plays an important role in the back-arc Africa-Europe subduction zone, acting as a bridge between two separate geological domains: the Aegean region and the western Anatolia extensional province. This geodynamic significance has been explored by **Jolivet et al., (2013), Ring et al., (1999, 2007), and Roche et al., (2019)**.

#### 4.5.1. Geology-Geomorphology of Samos

Samos is situated within the Hellenides medial tectono-metamorphic belt, located in the eastern Aegean arc, and is a part of the Attic–Cycladic Blueschist Unit, alongside Ikaria Island (as shown in **Figure 27**). The island's geological structure comprises alpine tectonic elements and post-alpine sedimentary basins (**Theodoropoulos, 1979**). These elements encompass both metamorphic and non-metamorphic layers, which include the Kerketeas carbonate platform, Aghios Ioannis unit, Ambelos nappe, Vourliotes nappe, and Kallithea nappe (**Papanikolaou, 1979; Papanikolaou, 2015; Ring et al., 1999; Roche et al., 2019**) (as mentioned in **Figure 28**). The island's E-W orientation is a result of Quaternary deformation, which has led to the formation of an E-W tectonic horst structure bounded by parallel fault zones along its northern and southern coastlines (**Chatzipetros et al., 2013**).

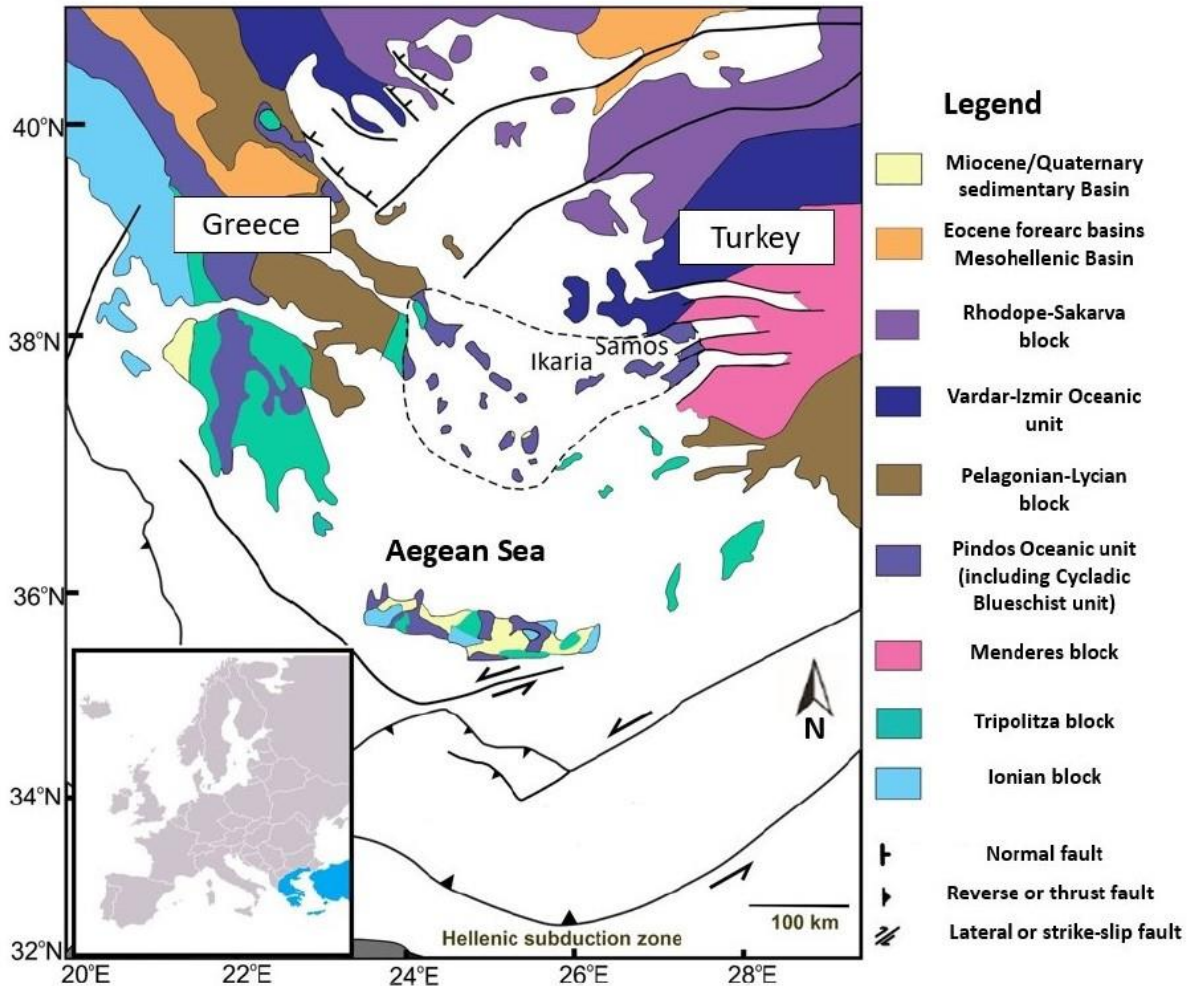


Figure 27. Geological formations in Greece and Turkey, modified (Mountrakis, 2006)

The Neogene sedimentary basins on the island feature N-S trending border fault systems along with volcanic intrusions during the initial stages of continental sedimentation (Theodoropoulos, 1979). The island's early geological history was characterized by east-west extension and north-south compressive events. Later, during the Early Pleistocene, there was a shift towards north-south extension and the activation of east-west normal faulting. This pattern of extension is consistent with what is observed in the broader area of the Eastern Aegean plate, encompassing the Eastern Aegean islands and the western coastal region of Minor Asia (Papanikolaou, 1979; Angelier, 1976; Nomikou et al., 2021; Nomikou et al., 2022; Aksu et al., 1987; Taymaz et al., 1991; Seyitoğlu & Scott, 1996; Yilmaz et al., 2000; Stiros et al., 2000; Kouskouna, 2021; Kiratzi et al., 2021).

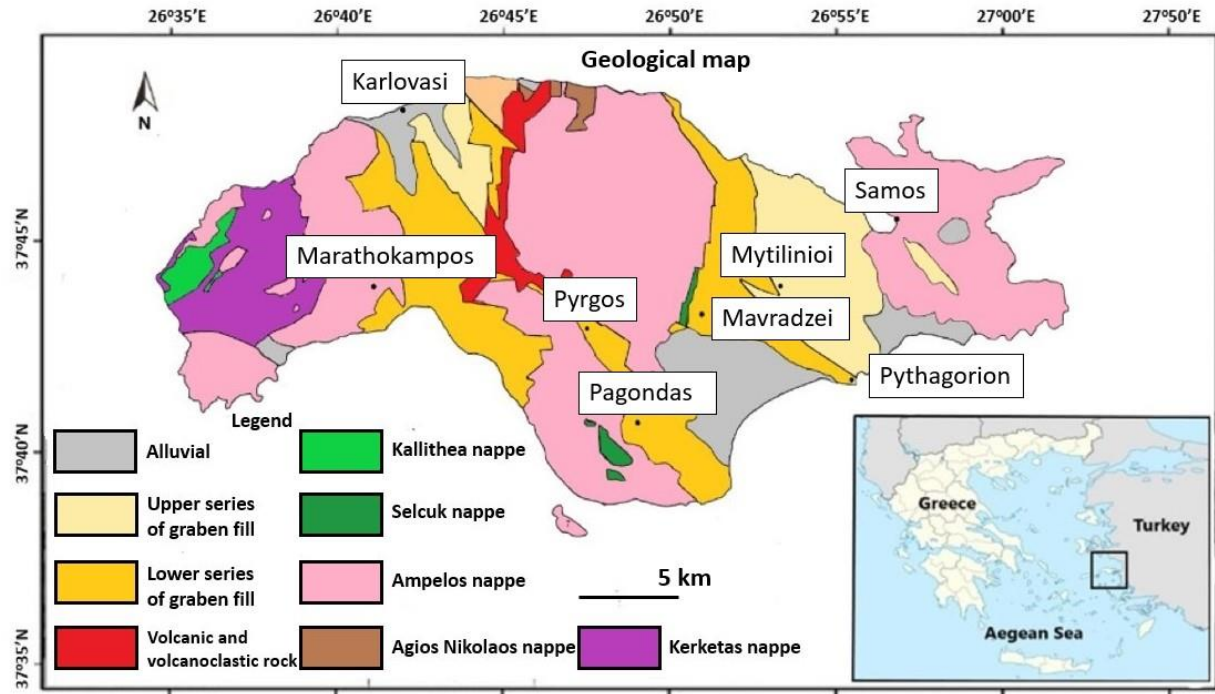


Figure 28. Geological map of Samos, modified (Ring et al., 1999)

The predominant geological forms visible on the island encompass marbles, shales, metamorphic rocks, granite-like formations, and volcanic intrusions, reflecting a multifaceted geological past (Papanikolaou, 1979). These geological features have been utilized for extracting resources on Samos, including construction materials, aluminum ores, borates, lead, silver, and clay ores, through mining and exploitation.

#### 4.5.2. The Paleontological Heritage of Samos

Samos distinguishes itself in the field of paleontology, drawing the attention of scientific investigations and excavations focused on its abundant fossil legacy. Discoveries made in the early 19th century established systematic categories for various species, which have since been used as models for naming newly discovered specimens. Notably well-preserved, fossils found in Samos often feature complete skulls, a rarity in locations rich in fossils where fragments are more commonly found (Solounias & Ring, 2007).

The Mytilinioi basin, located to the north of Mytilinioi village and to the east of the Ampelos massif, proves to be a fertile reservoir of fossils on the island. These fossils comprise a remarkable variety, consisting of 78 mammal species as well as 18 reptiles, birds, and snail species. Notably, the extensive collection of 78 mammal species in this fauna rivals, and in some cases even exceeds, the diversity of modern African savanna fauna, despite the animals in the past having larger territories (Solounias & Ring, 2007).

Fossils are concentrated in an area that covers less than one square kilometer, divided into nine distinct regions known as "bone beds" or "horizons," each spanning a few meters. Samos' fossil archive showcases a wide array of specimens (**Solounias & Ring, 2007; Solounias et al., 2010; Solounias, 1981a; Solounias, 1981b; Solounias & Mayor, 2004**). Particularly noteworthy are the mammalian ungulates, with some species represented by only a few specimens, while others are abundantly found, with over 20 individuals. Notable discoveries include hyenas, hippotheria, rhinoceroses, *Samotherium* (an extinct genus of Giraffidae from the Miocene and Pliocene of Eurasia and Africa), and various antelope species that inhabited this ancient ecosystem (**Solounias et al., 2010; Solounias, 1981a; Solounias, 1981b; Solounias & Mayor, 2004; Axelrod, 1975**).

The importance of the Samos fossils has several dimensions. Firstly, they shed light on the ancestors of contemporary species, contributing to a better understanding of evolutionary trajectories. Secondly, the composition of the fauna, which spans three continents, primarily reflects connections with species from central Africa, including those from rainforests and savannas, while connections to Asia are of secondary significance. It's worth noting that similarities with species from central Europe are relatively limited. This zoogeographical perspective assists in reconstructing the taxonomic distributions in the Late Miocene across these continents.

In the current context, the island's abundant plant life, influenced by a subtropical climate, probably supported subtropical evergreen sclerophyllous ecosystems with a mild climate (**Solounias & Ring, 2007; Solounias et al., 2010; Solounias, 1981a; Solounias, 1981b; Solounias & Mayor, 2004; Axelrod, 1975**).

A comparable set of plant species in Pikermi, situated near Athens, has been thoroughly documented by **Orgeta (1979)**, showing similarities with the plant life on Samos (**Ioakim & Solounias, 1985**). This observation led **Ioakim & Solounias 1985** to propose the idea of a proto-savanna environment for both Samos and Pikermi (**Solounias & Ring, 2007**), implying a relatively stable ecological condition on Samos for over a million years.

#### 4.5.3. The geological monuments of Samos

The geosites depicted in **Figure 29**, were meticulously chosen to ensure a comprehensive and meaningful assessment. These selections were made based on various criteria, including the frequency of tourist visits, UNESCO recognition, the diversity of geological characteristics, their conservation status, and their historical and cultural significance. A range of geological attributes were included, allowing us to assess the method's adaptability in different geological contexts. Furthermore, sites with varying conservation statuses and historical-cultural importance were included to assess the method's all-encompassing evaluation approach. This well-planned selection ensures a thorough assessment, underscoring the method's practical effectiveness and real-world applicability.

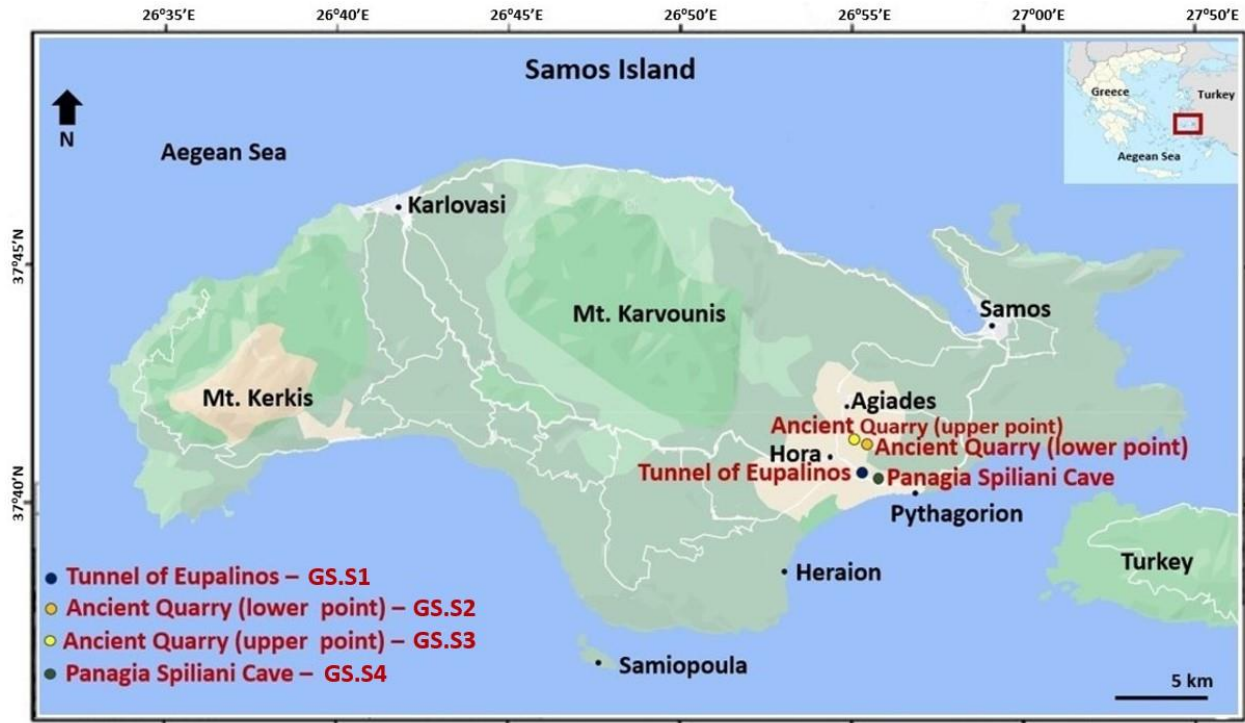
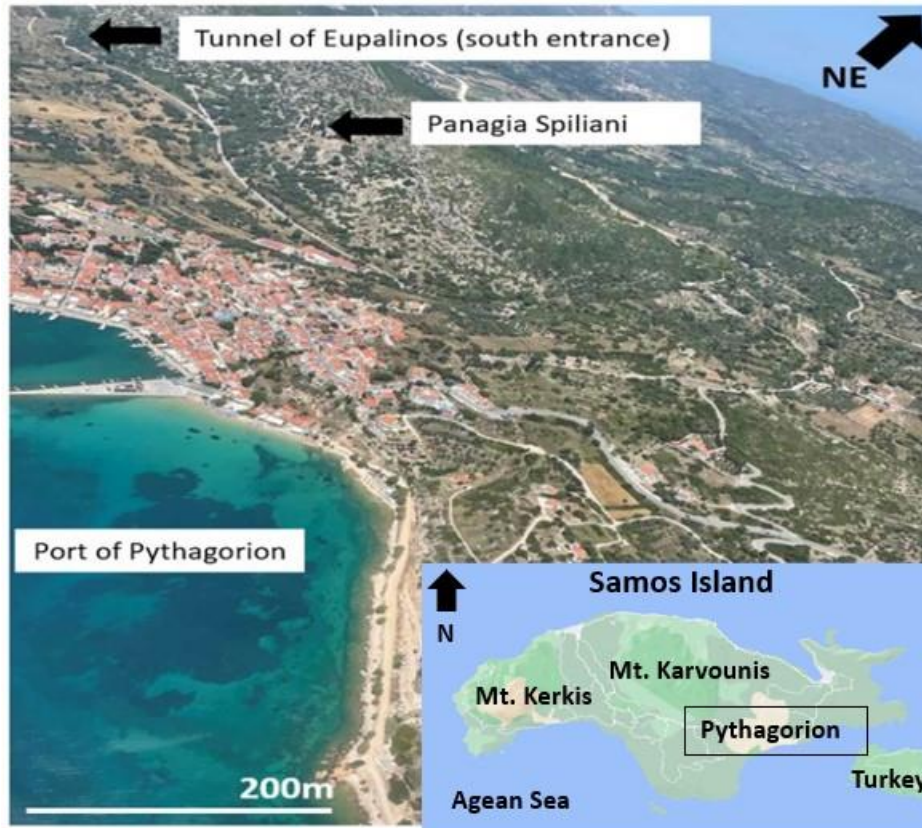


Figure 29. Satellite map of Samos indicating key locations on the island and the selected geosites

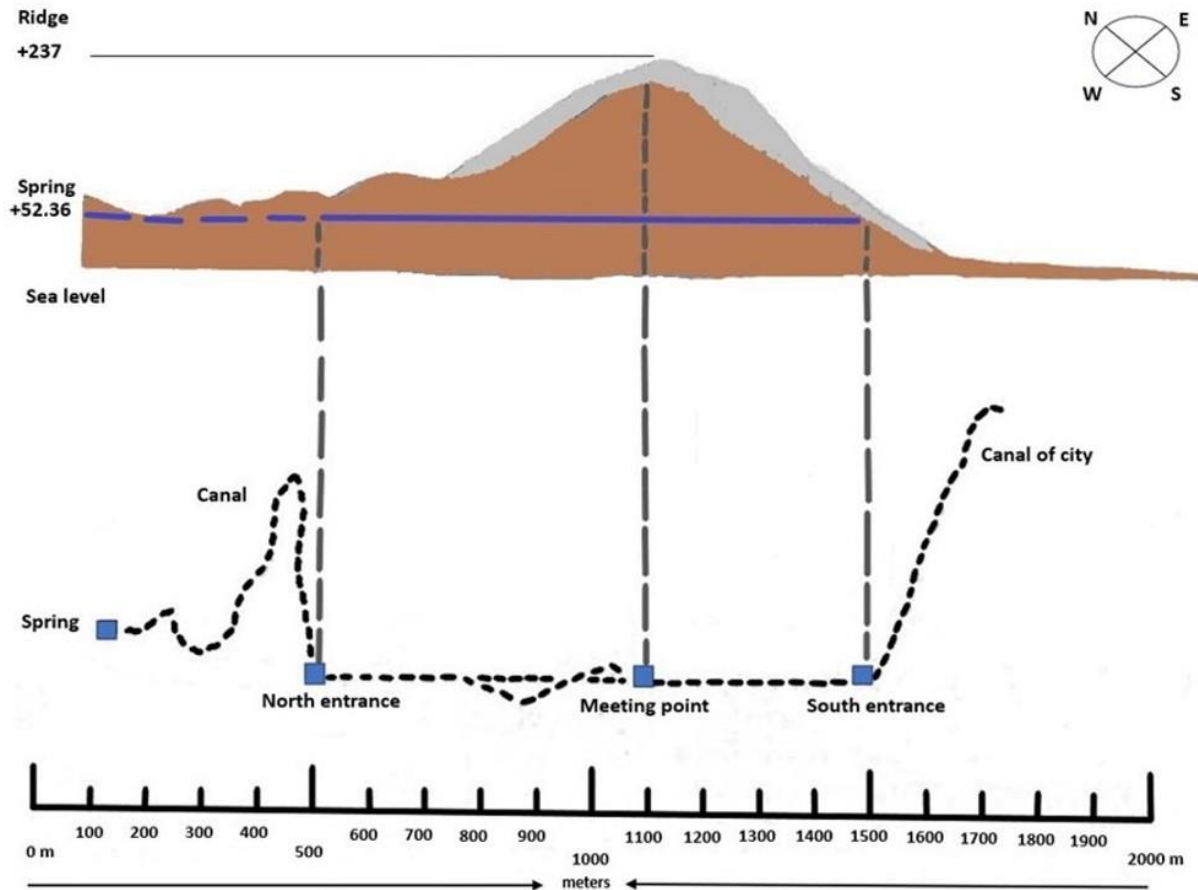
**GS.S1—The Tunnel of Eupalinos:** The Eupalinos Tunnel is located in the southeastern part of Samos, particularly in the wider area near Pythagorion (Figure 29 and Figure 30). Historically referred to as the "amphistomon orygma," as mentioned by the renowned historian Herodotus, it represents a highly significant achievement in the history of engineering. This ambitious project was completed during the reign of Polycrates in 520 BC and was overseen by the engineer Eupalinus (Angistalis et al., 2018).



**Figure 30.** Sweeping panoramic view showcasing the Pythagorion area, denoting the geotopes of the tunnel of Eupalinos (GS.S.1) and Panagia Spiliani (GS.S4) with clear markings

The tunnel was built to provide the ancient city of Samos, which is now called Pythagorean, with a dependable source of water. This water was obtained from a significant spring located further to the north at the Agiades site on Mount Ambelos, also commonly referred to as Mount Karvounis. Consequently, an extensive water distribution system with a total length of 2385 meters was set up, with 1035 meters of it passing through an internal tunnel.

The water channel originated from the Agiades source and maintained a consistent gradient of 0.6% over the initial 600 meters, with a relative depth of 2.5 meters. The following 260 meters followed a steady gradient of 0.75%. Subsequently, the pipeline entered a tunnel that stretched for 1035 meters, featuring an almost entirely horizontal alignment. The northern entrance was situated at an elevation of 55.48 meters, while the southern entrance was at 55.17 meters. The tunnel had dimensions of 1.80 x 1.80 meters and included a sloping tunnel floor that was 0.6 meters wide and descended to depths of up to 10 meters. Semicircular pipes, measuring 0.40 meters in width, were installed within this tunnel to facilitate water transport. Beyond the southern end of the tunnel, there was an additional 490-meter-long pipeline that used the natural terrain to transport water to the town's reservoir (see **Figure 31**). It's worth noting that, to expedite construction, excavation began simultaneously from both the northern and southern ends and met with minimal deviation (Seitanidis et al., 2006).



**Figure 31.** Simplified profile of the Eupalinos tunnel (GS.S1), modified (Seitianidis, 2003)

The Eupalinos tunnel unquestionably stands as an architectural masterpiece, attracting the attention of scholars from diverse disciplines (Seitanidis, 2003). This ancient tunnel is renowned for its innovative and complex design, as well as its historical significance. Its primary role was to function as an aqueduct, ensuring a dependable water supply to the ancient city of Samos. It's important to mention that this function was intricately tied to the geological features within the tunnel. The Tunnel of Eupalinos showcases the extraordinary engineering prowess of the ancient world, serving both practical and educational purposes. Its historical and hydrological importance underscores its status as a monument to human creativity.

In terms of its geological characteristics, the tunnel passes through sedimentary deposits from the Neogene age lake (Meissner, 1976). These deposits consist of tightly packed layers of mica or limestone with a northwesterly orientation. Eupalinus made a deliberate choice to tunnel in alignment with these strata, presumably because it made the excavation process more manageable. The excavation technique involved working from the bottom upwards, allowing the tunnel's roof to rest on a natural layer. The sidewalls were constructed robustly, running nearly parallel to the tunnel's sides. This ingenious design preserves the structural integrity of the tunnel without the need for additional support or specialized technical measures. Only a section of the

northern passage required limited interventions, primarily related to support implementation, possibly driven by technical or safety considerations.

Additionally, precise measurements taken within the tunnel reveal its capability to maintain consistent levels of humidity and temperature. To be specific, humidity levels range from 82% to 100%, while the temperature fluctuates between 15°C and 17°C. In contrast, the external environment experiences more pronounced variations in both temperature and humidity. These findings suggest that the Eupalinos tunnel operates as a dual karstic cave (**Seitanidis et al., 2006**). However, it's worth noting that this cave has been in use for only 25 centuries, a relatively short period that prevents significant cave formations from developing. **Kienast (1995)**, an expert on the tunnel, has identified the presence of stalagmites and stalactites in various sections of the tunnel, which can pose challenges to navigation.

The innovation of the Eupalinos tunnel stands in sharp contrast to the traditional underground QANAT systems, which are networks of underground water channels commonly used in arid regions and have their origins in ancient Iran, dating back to the early 1st millennium BCE. These QANAT systems slowly spread to the west and east from there. In QANATs, the underground aquifer becomes saturated with water, and the tunnel aligns with the gradient of the aquifer until it emerges as a spring. This method closely follows the geological, hydrological, and stratigraphic characteristics of the aquifer. In contrast, the Eupalinos tunnel disregards the gradient and the direction of groundwater flow (which is to the northeast). Instead, it bores horizontally, guiding water in a southeastern direction. This alteration significantly changes the path of the water within the tunnel. From this perspective, the Eupalinos tunnel can be seen as a technologically superior solution compared to QANAT systems (**Seitanidis et al., 2006**).

**GS.S2 & GS.S3— Ancient Quarries of Agiades:** The ancient quarries at Agiades can be found in the vicinity of the village of Mytilinios, one of the larger communities on Samos Island (**Figure 29**). In this area, a total of 45 caves have been recorded, with some of them serving as entrances to ancient quarries. These entrances exhibit hand-carved pillars, showcasing the skilled workmanship of the miners from that period (**Figure 32** and **Figure 33**). This precise construction has ensured the durability of these quarry entrances over time, as they have remained structurally sound without suffering collapses or structural problems.



**Figure 32.** The interior sight of the lower point of the ancient quarry (GS.S2)



**Figure 33.** The interior sight of the upper point of the ancient quarry (GS.S3)

These quarry locations played a significant role in the provision of materials for the construction of the impressive ancient Temple of Hera, which has held UNESCO World Heritage Site status since 1992 (Kienast, 1992). Furthermore, they supplied resources for other historical sites in the ancient city of Samos, which is now known as the Pythagorean. Scholarly research has identified two primary periods of mining activity in these areas: the Archaic and Roman eras (Tziligkaki & Stamatakis, 2018). During these periods, substantial limestone extraction took

place. Notably, two primary sites became central for the extraction and utilization of limestone resources, as illustrated in **Figure 32** and **Figure 33**. These sites also served as sources of nitrate salts, which played a critical role in gunpowder production during the 19th century (**Stamatakis & Zagouroglou, 1984**).

The more extensive mining location on Samos Island, depicted in **Figure 32** (lower point—GS.S2), is especially remarkable for its substantial size, with depths reaching about 50 meters and an average height of approximately 5 meters. The lower point quarry (GS.S2) stands as evidence of the expertise of ancient miners who supplied crucial materials for famous structures such as the Temple of Hera. This site is further subdivided into three segments by walls that are 1.50 meters wide.

The second location (upper point—GS.S3) is of a more modest size, with lesser depth and height, yet it continues to be an important reservoir of mineral resources (**Figure 33**). Although it's smaller in scale, the upper point quarry, GS.S3, holds historical significance owing to its contributions to ancient building projects and 19th-century gunpowder production, underscoring its multifaceted historical significance.

Both geosites, GS.S2 and GS.S3, provided unique, durable, hard porcelaneous and yellowish-brown limestones.

**GS.S4— Panagia Spiliani:** The Panagia Spiliani cave is located near the Pythagorio settlement, positioned at an elevation of 125 meters above sea level (**Figure 29** and **Figure 30**). By descending a series of 95 steps, visitors enter a spacious cave that houses a dedicated church in honor of the Virgin Mary. In its earlier history, this cave was used as a quarry to extract large limestone blocks, which were then utilized in constructing the walls and various structures for the town of Samos.

The Panaghia Spiliani cave is located within a Neogene limestone formation that was once part of a lake (**Ring et al., 1999**). The cave is renowned for the discovery of *Dolichopoda giulianae*, a species of cave-dwelling Orthoptera from the Rhabdophoridae family (**Rampini et al., 2012**). This species is found across a wide geographical range, stretching from the eastern Pyrenees to the Caucasus Mountains and extending further east to the Alborz Mountains in northern Iran. Many species in this genus have a strong preference for cave environments. However, it's noteworthy that within the northern part of their distribution range, *Dolichopoda* populations inhabit a variety of settings. These include soil crevices in forests, catacombs, Etruscan tombs, other human-made structures, natural caves, and extensive underground karst systems. This highlights a spectrum of habitats, ranging from partially aboveground to entirely subterranean conditions. Their life cycle duration varies based on the specific habitat they occupy, indicating adaptations to diverse environmental factors, including changing climate patterns and relatively stable conditions (**Di Russo et al., 1994**). The cave itself has a significant length of up to 120 meters, with an average width of 36 meters, and a relative depth of 8.5 meters. Within the cave, there is a temple, and the exterior is adorned by a monastery.

At present, the cave remains a place of religious worship (**Figure 34** and **Figure 35**). Nevertheless, the substantial and regular arrival of visitors has unintentionally resulted in adverse effects on the cave's interior decoration (**Kirdis & Papadopoulos, 2000**).



**Figure 34.** The entrance of the Panagia Spiliani cave (GS.S4)



**Figure 35.** The interior of the Panagia Spiliani cave (built in the 17th century) with the little church inside

# Chapter 5: Assessment Methods for Evaluating Geological Monuments

## 5.1. General

Natural landmarks, which are frequently captivating and popular tourist destinations (such as caves, gorges, river valleys, paleontological sites with dinosaur footprints, ancient lava flows, geysers, and so on), must be evaluated as part of the geotourism planning and management process. Natural landmarks have a significant impact on management, protection, and sustainable development in their surroundings (**Kubalíková, 2009**).

Numerous researchers have developed criteria for determining the intrinsic value of different kinds of geosites, which include both natural and manmade aspects. The criteria for evaluating natural landmarks take into account scientific, educational, aesthetic, and economic aspects (**Baca & Schuster, 2011; Bruschi et al., 2011; Fassoulas et al., 2012; Kubalíková, 2009; Pereira et al., 2007; Poirier & Daigneault, 2011; Reynard et al., 2007; Rybár, 2010; Tucki, 2004; Warszyńska, 1970, 1974; Wimbledon et al., 2000**). Generally, geosite assessment methods can be categorized into qualitative and quantitative approaches.

Qualitative assessment methods rely on descriptive site analysis without assigning specific scores or points. The principles of such evaluation were extensively discussed by **Wimbledon et al., (2000)** during a symposium in Rome. Criteria used in this method for site assessment include representativeness, uniqueness, sustainability, multidisciplinary study, availability, potential, complexity, and geodiversity. Since the outcomes of qualitative assessments provide textual descriptions, a deep understanding of the assessed phenomena is necessary. Consequently, these assessments are often more beneficial for professionals rather than the public.

Quantitative techniques for assessing landscapes and landforms began to emerge in the late 1960s. During this period, English-speaking scientists like Linton and Fines developed methods for evaluating landscapes as valuable natural resources (**Linton, 1968; Fines, 1968**). Additionally, in 1969, Leopold conducted a study on landscape aesthetics, and in 1970, **Warszyńska (1970)** proposed a quantitative methodology for evaluating areas of tourist interest. In the late 1990s, innovative evaluation approaches based on scientific criteria and geological values gained value (**Grandgirard, 1999; Giusti & González-Díez, 2000; Reynolds, 2001**). Throughout the late twentieth and early twenty-first centuries, new assessment approaches connected with geological principles and procedures were introduced, including both individual and collective efforts from geological research institutions.

Quantitative methods involve assigning specific point values to different criteria, with the total points determining the final value of the site. In general terms, the quantitative assessment of geotopes forms the cornerstone of the decision-making framework for geotourism development.

Although there has been an increase in research related to the numerical evaluation of geotopes over the past decade, there is still no universally accepted approach within the geological community. The primary challenge lies in the fact that the focus on evaluation criteria varies based on researchers' interests and perspectives, leading to a lack of objectivity. Quantitative methods typically revolve around a range of standards and relevant metrics, to which various scores or parameters can be assigned (**Bruschi & Cendrero, 2009; Bruschi et al., 2011; Bollati et al., 2013; Cendrero, 1996a; Cendrero, 1996b; Coratza & Giusti, 2005; Fassoulas et al., 2012; Pereira et al., 2007; Pereira & Pereira, 2010; Pralong & Reynard, 2005; Reynard et al., 2007; Reynard, 2009; Pereira & Pereira, 2012**). To fulfill the goals and criteria for the efficient preservation and management of a region's geological heritage, it is recognized that the systematic gathering and analysis of data regarding geosites is a crucial and fundamental undertaking (**Brilha, 2016**).

Another approach to assessing individual localities involves statistical methods, which combine qualitative and quantitative assessments by a group of experts according to specific criteria (**Bruschi et al., 2011; Fassoulas et al., 2012**). While this method is regarded as highly unbiased, its practical use can be difficult, particularly when analyzing numerous sites, as it necessitates input from several independent specialists. Furthermore, in some places, personal and professional biases may impede the execution of this strategy.

The section that follows is a summary of the most important assessment procedures used to evaluate geosites.

### 5.1.1 Method of Reynard et al., (2007; 2016)

**Reynard et al., (2016)** introduced an evaluation approach that builds on earlier methods (**Bruschi & Cendrero, 2005; Serrano & Trueba, 2005; Pereira et al., 2007; Pereira & Pereira, 2010; Reynard et al., 2007**). This method considers two primary values: scientific and additional, encompassing twelve subcriteria (detailed in **Table 1**). The scientific value is comprised of four subcriteria, while the additional value is further categorized into ecological, aesthetic, and cultural values. While this approach doesn't explicitly delve into the educational aspect of a geomorphosite, it does scrutinize concepts like religious, historical, artistic, bibliographic, and geohistorical significance, along with economic value, within the cultural value category.

**Table 1.** Assessment method of Reynard et al., 2016; Reynard et al., 2007

<b>Assessment Method of Reynard et al., 2016; Reynard et al., 2007</b>			
<b>(Scoring System 0, 0.25, 0.75, 1)</b>			
<b>Scientific Value (SV)</b>	<b>Additional Value (AV)</b>		
	<b>Ecological Value (ECOL)</b>	<b>Aesthetic Value (AEST)</b>	<b>Cultural Value (CULT)</b>
Integrity (Int)	Ecological impact (Eci)	Viewpoints (VP)	Religious importance (REL)
Representativeness (Rep)	Protected site (PS)	Contrasts, vertical development, and space structuration (STR)	Historical importance (HIS)

Rarity (Rar)	Artistic and literary importance (ART)
Paleogeographic value (Pgv)	Geohistorical importance (GEO)
	Economic value (ECON)
$SV = (\text{Int} + \text{Rep} + \text{Rar} + \text{Pgv})/4$	$AV = (\text{ECOL} + \text{AEST} + \text{CULT})/3$

### 5.1.2 Method of Pereira et al., (2007) and Pereira & Pereira, (2010)

**Pereira's et al., 2007** evaluation approach, along with its updated version by **Pereira & Pereira, 2010**, incorporates three key values (outlined in **Table 2**): intrinsic geomorphological value, potential utilization, and the requirement for preservation. The first value is further subdivided into five subcriteria, covering scientific, geomorphological, ecological, cultural, and aesthetic aspects. The potential utilization aspect includes three subcriteria, namely accessibility, visibility, and the potential exploitation of other natural or cultural values. The third value relates to the necessity for safeguarding and includes two subcriteria: the degradation and susceptibility of areas with geological significance. These two subcriteria were considered pioneering in their era. However, it's important to note that this assessment method doesn't explicitly address the geoeducational perspective.

**Table 2.** Assessment method of Pereira & Pereira (2010); Pereira et al., (2007)

Assessment Method of Pereira et al., (2007) and Pereira & Pereira (2010)		
Criteria		Assessment
Geomorphological intrinsic value (IV)	Scientific (Sc)	2—low; 3—medium; 4—high; 5—very high
	Other geomorphological values (Ogv)	0—nil; 1—very low;
	Ecological (Ec)	2—low; 3—medium;
	Cultural (Cul)	4—high; 5—very high
	Aesthetic (Ae)	
Potential use (PU)	Accessibility (Ac)	1—very difficult; 2—difficult;
	Visibility (Vi)	3—medium; 4—easy/good;
	Use of other natural or cultural values (Oth)	5—very easy/very good
Need for protection (NP)	Deterioration (De)	1—low; 2—medium;
	Vulnerability (Vu)	3—high

### 5.1.3 Method of De Wever et al., (2006; 2015)

The De Wever evaluation method, which was adopted by a French public geological research institution in 2006, is a framework for assessing the geological monuments' geoheritage significance and vulnerability (De Wever et al., 2006; De Wever et al., 2015). This approach is built upon two main criteria: (1) geoheritage significance and (2) vulnerability and the necessity for preservation (as detailed in **Table 3**). The geoheritage significance criterion is further subdivided into six subcriteria, encompassing primary geological significance, secondary geological relevance, educational importance, historical geology relevance, site uniqueness, and preservation status. These subcriteria are utilized to gauge the scientific and educational significance of a geosite. In contrast, the vulnerability and need for preservation criterion comprises four subcriteria: heritage significance, natural susceptibility, human-induced threats, and effective safeguarding measures. Ratings are awarded based on the assessment of geoheritage significance (as shown in **Table 3**). Notably, the De Wever assessment method makes a clear distinction in evaluating a site's educational potential as a separate subcriterion, recognizing the importance of public education about geoheritage. Consequently, the De Wever evaluation provides a comprehensive approach to determine the geoheritage value of geosites and pinpoint those that require enhanced protection measures.

**Table 3.** Assessment method of the national geosite inventorying of France, based on De Wever et al., 2006; De Wever et al., 2015

Assessment Method of the National Geosite Inventorying of France						
Geoheritage Interest				Vulnerability and Need for Protection		
Subcriterion	Scale	Coefficient	Geoheritage Interest Rating		Subcriterion	Scale
a Primary geological interest	0 (Minimal interest) 3 (Remarkable)	4	≤10	0 star	Heritage interest	0–3 (geoheritage interest star)
Secondary geological interest	0 (No interest) 3 (Remarkable)	3	11–20	1 star (*)	Natural vulnerability	0 (no threat) 3 (extreme threat)
Educational interest	0 (No interest) 3 (Remarkable)	2	21–30	2 stars (**)	Anthropic threats	0 (no threat) 3 (extreme threat)
Interest on the history of geology	0 (No interest) 3 (Remarkable)	2	31–48	3 stars (***)	Effective protection	0 (maximum) 3 (complete lack)
Rarity of the site	0 (Common) 3 (Rare)	3			Summation	12 points in maximum
Preservation status	0 (Poor) 3 (Good)	2				
Summation	48 points in maximum (scale * coefficient)					

### 5.1.4 Method of Zouros (2007)

**Zouros (2007)** introduced a novel approach for assessing the inherent worth of geological monuments, comprising six values and ten subcriteria. The initial value pertains to scientific and

educational aspects, encompassing four subcriteria: integrity, rarity, representativeness, and exemplarity. Other values encompass geodiversity, ecological-aesthetic factors, cultural relevance, threat potential, and the requirement for preservation, which comprises two subcriteria: vulnerability and legal safeguards. The ultimate value, usability potential, includes four subcriteria: recognizability, geographical spread, accessibility, and economic viability (outlined in **Table 4**).

**Table 4.** Assessment method of Zouros (2007)

<b>Assessment Method of Zouros</b>				
Scientific and educational value (Ranking 40–0)	Integrity (10–0)	Rarity (10–0)	Representativeness (10–0)	Exemplarity (10–0)
Geodiversity (Ranking 10–0)				
Ecological and aesthetic value (Ranking 10–0)				
Cultural Value (Ranking 10–0)				
Potential threats and protection needs (Ranking 10–0)	Legal protection (5–0)	Vulnerability (5–0)		
Potential for use (Ranking 20–0)	Recognizability (5–0)	Geographic distributior (5–0)	Accessibility (5–0)	Economic potential (5–0)

The key innovation of this method (**Zouros, 2007**) lies in its inclusion of legal safeguards and protection mechanisms for geologically significant sites. By doing so, it highlights the significance of preserving geosites with substantial scientific, educational, cultural, or economic value. Furthermore, this approach recognizes the possible risks that geosites may face and the necessity of assessing their vulnerability to harm or loss. This method establishes a comprehensive framework for assessing the inherent worth of geosites and identifying those that require protection and conservation.

### 5.1.5 Method of Fassoulas et al., (2012)

**Fassoulas et al., (2012)** introduced a quantitative approach to evaluate geotopes, with the goal of facilitating the sustainable management and preservation of geological heritage. This method employs a set of criteria that considers not just a geotope's geological and geographical importance but also its scientific, ecological, cultural, aesthetic, and economic significance.

The method concentrates on specific indices required for determining the values related to tourism, education, and the protection needs of geotopes. This proposed methodology employs a

scoring system to assess the value indices for tourism, education, and protection needs for each geotope, ranging from 1 to 10. These scores are derived from various criteria, including scientific, ecological, cultural, aesthetic, economic, and potential for use factors (refer to **Table 5**). This quantitative assessment approach enables the identification of priorities for sustainable tourism development, such as geotourism and educational tourism activities, along with the preservation of geotopes. This quantitative evaluation method offers a comprehensive framework for effective geoheritage management and protection, which is vital for the sustainable development of a region.

**Table 5.** Assessment method of Fassoulas et al., (2012)

<b>Assessment method of Fassoulas et al., (2012)</b>					
<b>Scientific Value</b>	<b>Ecological Value</b>	<b>Cultural Value</b>	<b>Aesthetic Value</b>	<b>Economic Value</b>	<b>Potential for Use</b>
(Scoring system 1, 2.5, 5, 7.5, 10)					
Geological history	Ecological impact	Ethics	Viewpoints	Visitors	Intensity of use
Representativeness	Protection status	History	Landscape difference	Attraction	Impacts
Geodiversity		Religious		Official protection	Fragility
Rarity		Art and culture			Accessibility
Integrity					Acceptable changes

### 5.1.6 M-GAM Method of Tomić & Božić, (2014)

The M-GAM (Modified Geosite Assessment Model) developed by **Tomić and Božić (2014)** is a combination of the GAM model created by Vujičić et al. (2011) and the importance factor (Im) first introduced by **Tomić (2011)** in his research. In this research project, the viewpoints of visitors were considered during the evaluation process. A survey was used to gather information. Along with the assessment criteria from **Vujičić et al., (2011) (Table 6)**, a new element called the importance factor (Im) was added to the evaluation process. This factor enabled visitors and tourists to express their thoughts on the significance of each subindicator in the assessment model. The M-GAM method has proven to be an effective and widely utilized tool in academia for evaluating the sustainable management and preservation of geoheritage (**Zafeiropoulos & Drinia, 2022**). One notable advantage of this assessment approach is its incorporation of perspectives from both experts and visitors (**Tomić & Božić, 2014; Antić et al., 2019**). Consequently, M-GAM is employed to evaluate the scientific, educational, and tourist worth of a geosite while also incorporating the perspectives of visitors, regardless of their level of geological knowledge. It's important to note that in this method, the assessment is conducted using a mathematical model, ensuring that both methods are evaluated impartially and independently of each other.

**Table 6.** M-GAM assessment method of Vujičić et al., (2011) and Tomić & Božić, (2014)

<b>Assessment Method of Vujičić et al., (2011) and Tomić and Božić, (2014)</b>					
(Scoring System 0, 0.25, 0.50, 0.75, 1)					

Main Values (MV)			Additional Values (AV)	
Scientific/Educational (VSE)	Scenic/Aesthetic (VSA)	Protection (VPr)	Functional (VF <sub>n</sub> )	Touristic (VTr)
Rarity	Viewpoints	Current condition	Accessibility	Promotion
Representativeness	Surface	Protection level	Additional natural values	Organized visits
Knowledge of geoscientific issues	Surrounding landscape	Vulnerability	Additional anthropogenic values	Vicinity of visitors center
Level of interpretation	Environmental fitting of sites	Suitable number of visitors	Vicinity of emissive centers	Interpretative panels
			Vicinity of important road network	Number of visitors
			Additional functional values	Tourism infrastructure
				Tour guide service
				Hostelry service
				Restaurant service
MV = VSE + VSA + VPr			AV = VF <sub>n</sub> + VTr	

In this method, there are two primary components considered: the main values (*MV*) and the additional values (*AV*). The core values consist of 12 criteria, focusing on the non-living attributes of a geosite, while the supplementary values primarily pertain to the human activities associated with each geosite and are comprised of 15 criteria.

The primary values encompass three key aspects: scientific and educational value (VSE), scenic and aesthetic value (VSA), and protection (VPr). Within the VSE category, considerations include rarity, representativeness, knowledge of scientific significance, and interpretative potential. The VSA component considers viewpoints, surface characteristics, the surrounding landscape and natural elements, as well as how well it fits into the environment, which involves aspects like color contrast and shape appearance relative to the natural surroundings. Lastly, the VPr field incorporates factors like the current condition, level of protection, vulnerability, and the suitable number of visitors. The calculation of the main values is determined by the equation:

$$MV = VSE + VSA + VPr$$

The additional values consist of two parameters: functional values (VF<sub>n</sub>) and touristic values (VTr). The assessment of the additional values is derived from the equation:

$$AV = VF_n + VTr$$

As previously stated, this method considers the visitors' viewpoint. This is incorporated in the importance factor (Im), which is independently assessed by the visitor for each field (rarity, representativeness, etc.) and multiplied by each corresponding subindicator (which is given by experts). In our study, we relied on **Tomić & Božić, (2014)** research for the importance factor,

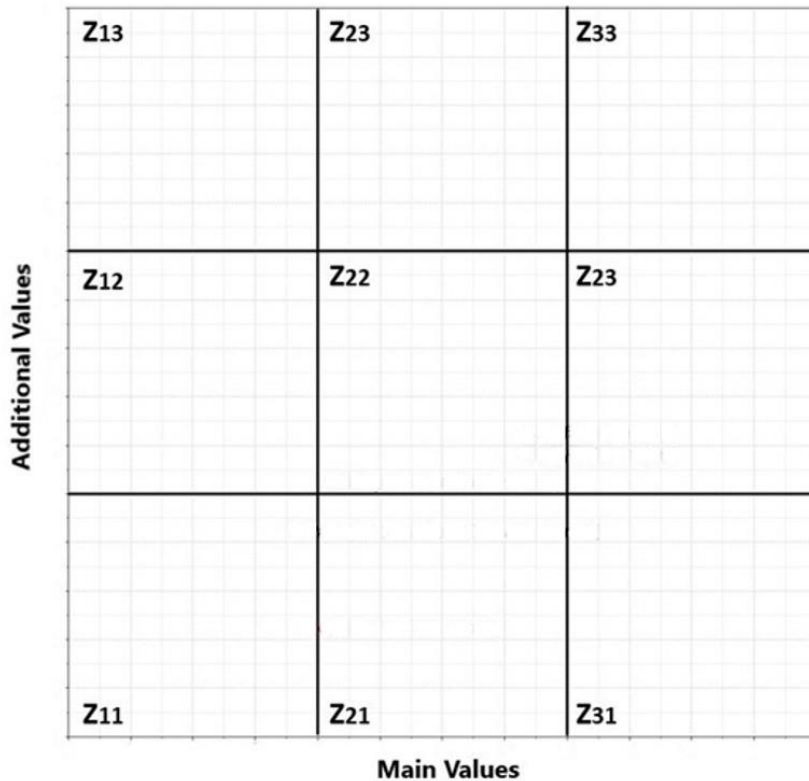
which has values including 0.00 (not at all important), 0.25 (not quite important), 0.50 (neither insignificant nor important), 0.75 (a little important), and 1.00 (quite great importance). The importance factor is defined by the following formula:

$$Im = \frac{\sum_{k=1}^K Ivk}{K}$$

where, *Ivk* represents the assessment or rating given by each visitor for each field or sub-indicator, and *K* denotes the total number of visitors.

Continuing the tradition initiated by **Antić et al., (2019)** who incorporated data and findings from **Božić & Tomić, (2015)** in their geosite evaluation study, we adopted the importance factor values from the identical publication by **Božić & Tomić, (2015)**.

The final outcomes produced by this approach are visualized in a graph, with the 12 main value categories positioned along the vertical axis and the 15 additional value categories along the horizontal axis. Moreover, this graph is divided into nine sectors, delineated as follows: commencing at the origin of the axes and corresponding to the x-axis in zones Z11, Z21, and Z31; ascending to the y-axis in zones Z12, Z22, Z23; and lastly, in zones Z13, Z23, and Z33 (**Diagram 3**). The diagram illustrates the ultimate score for each study area.



**Diagram 3.** The way of the depiction of the results in M-GAM method

### 5.1.7 The GP method of Brilha (2016)

**Brilha's (2016) method** is classified as a general-purpose approach (GP method) designed to assess various types of geosites by employing a set of criteria (outlined in **Table 7**).

This method presents a quantification framework comprising four factors: scientific value (SV), potential educational use (PEU), potential touristic use (PTU), and degradation risk (DR).

The quantitative assessment of a geosite's scientific value (SV) encompasses seven criteria, namely: representativeness, key locality, scientific knowledge, integrity, geological diversity, rarity, and use limitations. "Representativeness" assesses a geosite's ability to showcase a geological process or a variety of features. "Key locality" signifies the significance of the geosite as a reference point for various geological features. "Scientific knowledge" comes into play when there are national or international publications associated with the geosite. "Integrity" pertains to the preservation status of the geosite. "Geological diversity" measures the diversity of distinct geological elements found within each geosite. "Rarity" examines whether there are geosites with comparable characteristics in the same area. Lastly, "use limitations" encompasses the obstacles and constraints that may hinder research and study of the geosite.

Regarding the quantitative evaluation of the educational potential use (PEU), twelve criteria are taken into consideration. These criteria include the susceptibility of a geosite to visitor impact, its level of accessibility, any usage restrictions that may apply, safety considerations, logistical aspects, the density of the local population, its connections to other values like cultural or aesthetic significance, the scenic quality of the site, its uniqueness, conditions for observation, and its educational potential. Vulnerability focuses on identifying geological elements that could be adversely affected by visitors. Additionally, this method examines the ease of access to the geosite, including any usage restrictions that might be in place. Safety conditions and potential amenities are also assessed. Moreover, the local population density and any affiliations of the geosite with other values, such as cultural or aesthetic importance, are determined. The assessment method also considers the scenic beauty of the area and its distinctiveness. Furthermore, it evaluates the conditions for observation and the potential for educational purposes.

To quantitatively assess the geotouristic potential (PTU), thirteen criteria are employed. The initial ten criteria align with those utilized for educational purposes. Additionally, the assessment considers the geosite's interpretative potential, the economic status of the local residents, and its proximity to recreational areas.

Degradation risk (DR) pertains to the likelihood of a geosite experiencing harm or deterioration, which could result in the loss of its valuable geological attributes (**Reynard, 2009; Pereira & Pereira, 2010; Carcavilla et al., 2007; Fuertes-Gutiérrez & Fernández-Martínez, 2012**). To assess and quantify degradation risk (DR), **Brilha (2016)** suggests the use of five criteria:

the deterioration of geological elements, proximity to areas or activities with the potential to cause degradation, legal protection status, accessibility, and population density.

Each of the criteria received a rating ranging from one to four points. In the case of SV, PEU, and PTU, a score of one indicates a low potential for use, whereas a score of four signifies a high potential for use.

It is important to note that the criteria utilized in this study are subjective, meaning they were customized to suit the specific characteristics of the area under investigation.

The second phase of the geosite quantification process involves assigning weights to the criteria. Weights were allocated to each of the quantification criteria based on their significance in evaluating the potential for scientific, educational, and tourist use. Additionally, weights were assigned to each criterion to gauge its importance in assessing the degradation risk of geosites, following the methodology of **Brilha (2016)**. In this context, the score of a geosite is calculated as the sum of:

$$SV = \text{representativeness} * 30 + \text{key locality} * 20 + \text{scientific knowledge} * 5 + \text{integrity} * 15 + \text{geological diversity} * 5 + \text{rarity} * 15 + \text{use limitations} * 10$$

The educational potential (*PEU*) is determined as follows:

$$PEU = \text{vulnerability} * 10 + \text{accessibility} * 10 + \text{use limitations} * 5 + \text{safety} * 10 + \text{logistics} * 5 + \text{density of population} * 5 + \text{association with other values} * 5 + \text{scenery} * 5 + \text{uniqueness} * 5 + \text{observation conditions} * 10 + \text{didactic potential} * 20 + \text{geological diversity} * 10$$

Lastly, the geotouristic potential (*PTU*) is calculated as:

$$PTU = \text{vulnerability} * 10 + \text{accessibility} * 10 + \text{use limitations} * 5 + \text{safety} * 10 + \text{logistics} * 5 + \text{density of population} * 5 + \text{association with other values} * 5 + \text{scenery} * 15 + \text{uniqueness} * 10 + \text{observation conditions} * 5 + \text{interpretative potential} * 10 + \text{economic level} * 5 + \text{proximity of recreational areas} * 5$$

Regarding the assessment of degradation risk (*DR*), it is determined by the sum of:

$$DR = \text{deterioration of geological features} * 35 + \text{proximity to areas/activities with potential to cause degradation} * 20 + \text{legal protection} * 20 + \text{accessibility} * 15 + \text{density of population} * 10$$

With the utilization of these criteria, it becomes feasible to categorize geosites into low, medium, or high degradation risk levels, employing the classification system established by **Brilha (2016)**.

According to the G-P method classification, geosites can be categorized as having low, medium, or high degradation risk, depending on the criteria.

Table 7. Assessment method of Brilha (2016)

Assessment Method of Brilha (2016)							
Scoring System 1, 2,3, 4 (Value of 3 is omitted at SV)							
Scientific Values (SV)		Potential Educational Use (PEU)		Potential Touristic Use (PTU)		Degradation Risk (SR)	
Criterion	Weight	Weight	Criterion	Criterion	Weight	Criterion	Weight
Representativeness	30	10	Vulnerability		10	Deterioration of geological elements	35
		10	Accessibility		10		
Key locality	20	5	Use limitations		5	Proximity to areas/activities with potential to cause degradation	20
Scientific knowledge	5	10	Safety		10		
		5	Logistics		5		
Integrity	15	5	Density of population		5	Legal protection	20
Geological diversity	5	5	Association with other values		5		
				5	Scenery		15
Rarity	15	5	Uniqueness		10	Accessibility	15
Use limitations	10	10	Observation conditions		5		
		20	Didactic potential	Interpretative potential	10	Density of population	10
		10	Geological diversity	Economic level	5		
				Proximity of recreational areas	5		

### 5.1.8 Method of Suzuki & Takagi, (2018)

Suzuki and Takagi's evaluation method for geotopes (Suzuki & Takagi, 2018) was primarily influenced by two earlier approaches (Zouros, 2007; Pralong, 2005) and had a strong emphasis on assessing their scientific significance. This method revolved around five fundamental values, each comprising three subcriteria (outlined in Table 8). The first value pertained to educational significance, and its assessment considered the geotope's historical clarity, representativeness, and the ease with which the information presented at the site could be understood. The second value centered on scientific importance, which was evaluated based on the research relevance, clarity, and reliability of the scientific content found in textbooks and other sources, along with the rarity of the geotope in the region. The third value concentrated on tourism-related aspects, encompassing aesthetic and sensory appeal, as well as the presence of other natural and human-made attractions in the vicinity. The fourth value examined safety and accessibility, considering the safety of the geotope and its access route, the distance from the information center to the geotope, and the walking time required from a transportation stop. Lastly, the fifth value focused on tourist information quality, considering factors such as information panels, digital resources, brochures, tour guides, and international information resources available in multiple languages.

**Table 8.** Assessment method of Suzuki & Takagi, (2018)

<b>Assessment Method of Suzuki and Takagi, (2018)</b>	
(Scoring criteria 1, 2, 3, 4)	
<b>Ved Education Value</b>	
Ved <sub>1</sub>	Ease of understanding the geosite's story
Ved <sub>2</sub>	Representativeness
Ved <sub>3</sub>	Ease of understanding information panels at the geosite
<b>Vsc Scientific value</b>	
Vsc <sub>1</sub>	Research significance
Vsc <sub>2</sub>	Clarity and non-obsolescence of scientific story on information panels, guidebooks, and websites
Vsc <sub>3</sub>	Rarity in the region
<b>Vtr Tourism value</b>	
Vtr <sub>1</sub>	Emotional/aesthetic value such as beauty or impressiveness
Vtr <sub>2</sub>	Other natural/anthropogenic values
Vtr <sub>3</sub>	Other tourist attractions in the vicinity
<b>Vsa Safety and accessibility</b>	
Vsa <sub>1</sub>	Safety condition of geosite and footpath
Vsa <sub>2</sub>	Travel time from the base (information) point of the area's attractions
Vsa <sub>3</sub>	Walking time from bus/train stops or parking lot
<b>Vti Value of tourism information</b>	
Vti <sub>1</sub>	Information panels of the approach to geosite
Vti <sub>2</sub>	Geosite information on websites, pamphlets, guidebooks, etc.
Vti <sub>3</sub>	International usefulness of information panels and websites (multilingual)

This method placed a significant focus on the geological heritage and the potential for geotourism in geological regions, leading to its extensive adoption and acknowledgment. It has been employed to boost urban geotourism and showcase the geological heritage of cities such as Segovia in Spain (Vegas, 2000) and Athens in Greece (Drinia et al., 2022). In summary, this method has a solid foundation and proves effective in advancing urban geotourism and showcasing the geological characteristics and landmarks found within urban settings.

## Chapter 6: On the creation of an innovative Geoeducational Assessment Method - GEOAM

### 6.1. Introduction

Evaluation of geological monuments is crucial for their protection, sustainable development, teaching, decision-making, and international cooperation. Despite the existing assessment tools, the urgent need for a particular technique that focuses on geosites' educational potential and ethical standards arose. The GEOeducational Assessment Method (GEOAM) fulfills this demand by offering a complete scheme for the assessment of geoheritage's teaching aspects. GEOAM improves geoeducation by the inclusion of geology teaching in the school curriculum, thus, students are made able to respect and understand their geological heritage. GEOAM, which consists of concepts such as geoconservation and geoethics, provides a standardized assessment mechanism for the development of educational programs. Its availability to teachers, educational personnel, and the public raises geoheritage awareness, promotes sustainable development, and fosters environmental responsibility.

GEOAM's two components—assessment and promotion—were created in response to the need to properly assess and promote geoeducation and geotourism inside geosites.

The assessment component of GEOAM covers several essential needs. To begin, traditional geosite assessment approaches often concentrate on scientific, educational, artistic, or commercial values in isolation. GEOAM combines these dimensions to provide a comprehensive assessment of geosites, making sure every aspect of a site's value is examined. Second, GEOAM stresses the educational value of geosites, demonstrating how they can be used as learning materials. This emphasis is crucial for raising geoheritage awareness and educating students and the public about geological and environmental procedures. Third, present assessment methods may not be consistent or objective. GEOAM solves this by defining explicit criteria and a scoring system, which improves the transparency and reproducibility of the review process. Finally, a strong evaluation tool like GEOAM provides important data for policymaking, conservation efforts, and geotourism development. This information enables stakeholders to recognize the importance of geological sites and manage their preservation and utilization.

The promotional aspect of GEOAM is similarly crucial. Assessing geosites independently is insufficient; effort must be made to communicate their significance to a larger audience. The promotion component seeks to enhance awareness of the value of geoheritage within local communities, instructors, and tourists. This component attempts to integrate geoeducation into school curricula and community activities through specialized courses, workshops, and resources, so helping to foster a culture of geological heritage awareness and management. Furthermore, by organizing events, creating learning resources, and using digital platforms, the promotion

component seeks to engage people in geoeducation and geotourism operations resulting in increased interest and participation in geosite preservation. Promotional initiatives also contribute to sustainable development by emphasizing geotourism's economic and cultural benefits. Educating local people and tourists on environmentally friendly practices guarantees that geosites are used appropriately, balancing economic rewards and conservation. Finally, successful promotion helps develop a rationale for geoheritage conservation and geoeducation programs, urging politicians to provide resources and support to these areas, and creating a broader network of support for sustainable geotourism and educational policies.

## 6.2. GEOAM as an assessment tool

### 6.2.1. Criteria Selection and Definition

An objective evaluation tool is characterized by its ability to produce consistent and unbiased results, regardless of the user. In the case of GEOAM, achieving objectivity entails the establishment of clearly defined criteria, transparent evaluation procedures, and regular calibration and validation of the tool's outcomes. Feedback from diverse stakeholders also plays a crucial role in maintaining objectivity. The criteria incorporated into GEOAM to enhance the geoeducational potential encompass accessibility, safety, vulnerability, conservation and protection of natural resources, environmental impact, environmental education and interpretation, cultural and historical significance, community involvement and engagement, economic viability, sustainable development, and geoethics.

**Accessibility** pertains to the ease with which a geotope can be visited and explored, considering factors such as proximity to urban centers and availability of amenities. Safety assesses potential risks associated with visiting a geotope, prioritizing visitor well-being and accident prevention. **Vulnerability** evaluates a geotope's susceptibility to external factors like human activity and natural disasters, with a focus on preserving fragile features and ecosystems. **Conservation and protection of natural resources** gauge efforts to safeguard the site's ecological integrity and minimize human-induced impacts.

**Environmental impact** considers the potential consequences of tourism activities on the geotope's ecosystem and surrounding environment. **Environmental education and interpretation** focus on initiatives aimed at educating visitors about environmental conservation and sustainability, fostering an understanding of the site's significance. **Cultural and historical significance** assesses the geotope's contribution to local heritage and history. **Community involvement** evaluates initiatives that engage local communities in decision-making and promote sustainable practices.

**Economic viability** examines the site's capacity to generate revenue for the local economy through sustainable tourism practices. **Sustainable development** evaluates the site's contributions

to economic, social, and environmental well-being. **Geoethics** scrutinizes the ethical principles governing the study and management of natural resources, ensuring responsible stewardship.

While these criteria offer a comprehensive framework for assessing geoh heritage sites, their practical application may pose challenges, particularly in assessing numerous sites comprehensively. To address this, criteria like accessibility and vulnerability can be grouped into categories, prioritizing essential aspects like "**site management and visitor experience—(SMVE)**", while conservation status and environmental impact were placed under the "**natural resource management—(NRM)**" category. Additionally, criteria should be tailored to each geotope, considering its unique attributes and context. Despite the need for flexibility, certain fundamental criteria such as accessibility and vulnerability should be consistently considered to ensure a holistic evaluation of geoe educational potential. By adapting the evaluation process to each geotope's specific circumstances, GEOAM aims to provide a nuanced understanding of its educational value and contribute to sustainable development and environmental stewardship efforts.

### 6.2.2. Grading System

The next step is to evaluate the geological monuments against the above criteria. This process involves determining whether each criterion is present and then assigning a score based on the degree to which the criterion is met. It is important to note, however, that if a single criterion is too broad and complex to assess comprehensively, it may be necessary to break it down into smaller, more precise sub-criteria, which can then be assessed separately. With this in mind, the category "Site Management and Visitor Experience-SMVE" can be assessed using the following sub-criteria:

1. Accessibility: Evaluation of the ease with which a site can be reached and its connection to other relevant tourist destinations or transport centres.
2. Signposting and interpretation. Examining the availability and quality of interpretive materials, such as brochures, maps and signs, to help visitors understand the geology and other characteristics of the site.
3. Staff knowledge and interaction with visitors: Assessing the training level of staff and their ability to interact with visitors, answer questions and provide information about the geology and other features of the site.
4. Visitor facilities: Assessing the presence and quality of visitor facilities such as restrooms, benches and trails.
5. Site maintenance: Assessing the level of maintenance and conservation of the site, including tasks such as litter removal, trail maintenance and facility upkeep.
6. Safety and security: Assessing the measures in place to ensure visitor safety, including warning signs, barriers and emergency response plans.

The following sub-criteria were considered in the evaluation of "Natural Resource Management - NRM

1. Biodiversity conservation: Assessment of efforts to protect and conserve plant and animal diversity, including rare or endangered species.
2. Preservation of ecosystems: Assessment of efforts to conserve natural ecosystems, including forests and wetlands.
3. Sustainable natural resource use: managing natural resources such as water, soil, minerals and timber in a way that minimises negative environmental impacts.
4. Assessment of pollution prevention and control measures, such as air and water pollution, solid waste management and hazardous waste management.
5. Climate change mitigation and adaptation: Assessment of the site's strategies for reducing greenhouse gas emissions, implementing renewable energy, and promoting sustainable transportation.

To evaluate "environmental education and interpretation—EEI," the following criteria can be employed:

1. Availability of interpretive signage or exhibits: This evaluates whether there are informative and captivating displays or exhibits that offer accurate insights into the site's natural and cultural history, ecological processes, and conservation efforts.
2. Access to skilled interpretive staff or volunteers: An assessment of the availability of trained staff with extensive knowledge of the site's resources and the ability to provide informative and engaging tours or educational programs.
3. Integration of environmental education and interpretation into the management plan: This criterion assesses how well these activities are integrated into the site's management plan, including adequate resources and support.
4. Integration of interactive and hands-on activities: This assesses whether visitors can actively engage with the site's natural resources and learn about their ecological and cultural significance.
5. Environmentally friendly practices: This considers whether the site's operations include waste reduction, energy conservation and the use of sustainable materials.

To grade "cultural and historical significance—CHS," you can consider the following subcriteria:

1. Historical significance: Assess the historical significance of the site, encompassing its cultural heritage and its association with pivotal historical events.
2. Cultural significance: Examine the cultural importance of the site, including its role in local communities and its influence on local culture.
3. Evaluation of the site's interpretive and educational programs, including materials, guided tours, and other forms of engagement.

4. Cultural diversity and inclusivity: Evaluation of the site's commitment to representing diverse cultural perspectives, including underrepresented cultures and marginalized groups.

To assess "community involvement and engagement—CIE," you can consider the degree to which the local community is engaged in the management, development, and promotion of the geosite. Here are some pertinent subcriteria for evaluating community involvement and engagement:

1. Stakeholder participation: Evaluate the level of engagement of the local community and other stakeholders in decision-making processes related to the geosite, including the development of management plans, proposals for development, and marketing strategies.
2. Cultural sensitivity: Assessment of the geosite's engagement in preserving the history and traditions of the community, as well as its ability to engage in a culturally sensitive manner.
3. Community benefits: Assessment of the impact of the geosite on the local economy, society and culture. This includes issues such as job opportunities, income generation, educational resources, and the enhancement of community pride.
4. Outreach and communication: Evaluation of the effectiveness of the geosite in communicating with the local community and stakeholders. Consideration should be given to how effectively the site involves them in planning, management and promotion of the geosite.

One way to evaluate "Geoethics-GE" is to consider the following sub-criteria:

1. Environmental impact: This determines whether the geosite is managed in a sustainable and responsible manner. It examines how human activities affect the environment and whether efforts are made to conserve natural resources. This assessment covers issues such as air and water quality, biodiversity and the overall health of ecosystems.
2. Cultural heritage: The focus of this criterion is to determine whether the geosite is managed in a way that respects and protects the cultural heritage of the local community. It examines efforts to protect archaeological and historical sites of cultural significance.
3. Social responsibility: This sub-criterion evaluates the impact of human activities on local communities. It assesses whether the management of the geosite promotes social responsibility, equity and human rights.
4. Transparency and accountability: This aspect assesses the site's management's transparency and accountability in providing public information, engaging stakeholders, and adhering to applicable laws and regulations. It includes an evaluation of the accessibility of information about the site's activities, stakeholder decision-making processes, and adherence to legal and regulatory requirements.
5. Professional conduct: The behaviour and actions of the site's professionals are assessed under this sub-criterion. It includes their commitment to ethical values, their ability to manage conflicts of interest, and their compliance with the rules and codes of conduct of

their profession. It is based on whether these professionals demonstrate integrity, honesty and a commitment to ethical practice in making decisions and interacting. It also considers their ability to remain objective and avoid bias.

The "economic viability–EV" criterion can be evaluated by considering the following subcriteria:

1. Tourist revenue potential: This subcriterion examines the geosite's capacity to attract tourists and generate revenue. Factors considered include the site's accessibility, attractiveness, and uniqueness.
2. Local economic impact: The contribution of the geosite to the local economy is assessed under this sub-criterion. It considers aspects such as the creation of jobs, the generation of income and the overall economic impact on the community.
3. Sustainability of economic benefits: This sub-criterion assesses the long-term sustainability of the economic benefits generated by the geosite. Consideration is given to factors such as economic diversification, the long-term viability of the site and the potential for adverse impacts.
4. Cost effectiveness of management: This sub-criterion assesses the efficiency and effectiveness of the geosite in delivering economic benefits. It considers operational efficiency, effectiveness and management accountability.
5. Innovative economic models: This sub-criterion focuses on the geosite's ability to promote sustainable development through innovative economic models. It includes factors such as entrepreneurship, social and environmental innovation.

Finally, there are several different variables to consider when assessing the Sustainable Development (SD) of a geosite. These include:

1. Resource efficiency: This factor examines how effectively resources such as energy, water and materials are used in the management of the geosite. It assesses whether resources are used efficiently and sustainably.
2. Waste management: This criterion assesses the management of waste at the geosite, including visitor and operational waste. It examines waste reduction, reuse, recycling and responsible disposal to ensure minimal environmental impact.
3. Biodiversity conservation: These variable measures efforts to conserve biodiversity. It considers whether the management plan protects endangered species and their habitats.
4. Social and economic impacts: This criterion assesses the social and economic impacts of the geosite on nearby communities. It looks at whether the geosite provides economic benefits and whether its management minimises negative social impacts.
5. Adaptation to climate change: This examines the ability of the geosite to adapt to the effects of climate change, such as rising sea levels, increased storm intensity and shifts in rainfall patterns. It also looks at whether the site's management plan includes ways to adapt to climate change.

6. Heritage conservation: This variable assesses efforts to protect the cultural heritage of the geosite. It assesses whether the management plan includes measures to preserve cultural heritage resources and how effectively these measures are put into practice.

The total score would be determined by the criteria, subcriteria, and grading scale employed in the evaluation. Each criterion in GEOAM is assigned a score upon a 1–5 scale, with each criterion being assessed based on the extent to which it is present or applicable. A score of 1 indicates ‘low presence’ or ‘low implementation,’ whereas a score of 5 indicates ‘very high presence’ or ‘extremely high implementation’ (**Table 9**). This provides a more elaborate assessment of a geosite’s geoeucational potential and ethical values while remaining accessible to both specialists and non-specialists.

**Table 9.** Characterization of the final score in GEOAM

$1 < \text{final score} < 2$	Low implementation
$2 \leq \text{final score} < 3$	Medium implementation
$3 \leq \text{final score} < 4$	High implementation
$4 \leq \text{final score} < 4.5$	Very high implementation
From 4.5 up to 5	Extremely high implementation

However, it's important to acknowledge that the specific grading scale applied to each criterion can be adjusted as needed based on the requirements and context of the assessment. The individual scores for each criterion would then be combined using the designated weights to calculate an overall score. In practical terms, if the grading scale for each criterion ranged from 1 to 5, with 5 indicating the highest score and 1 representing the lowest score, the **overall score** for a geotope would be determined by multiplying each criterion score by its assigned weight and summing up these values (**Appendix A**):

**Overall score =**

$$[(\text{SMVE} \times 0.10) + (\text{NRM} \times 0.10) + (\text{EEI} \times 0.30) + (\text{CHS} \times 0.10) + (\text{GE} \times 0.20) + (\text{EV} \times 0.05) + (\text{CIE} \times 0.05) + (\text{SD} \times 0.10)]$$

The process of assigning weights to each criterion and subcriterion can be further refined to enhance objectivity through various methods. In our approach, we engaged a panel of experts and stakeholders who possess expertise and experience in the fields of geotourism and geoconservation. This panel was responsible for evaluating the significance and relevance of each criterion and subcriterion, and subsequently, they allocated weights based on their assessments. By involving this diverse group of experts and stakeholders in the process, we obtained a set of weights that reflects a broad range of viewpoints and recognizes the intricate and multifaceted nature of geotourism and geoconservation.

### 6.3. GEOAM as a promotional tool

GEOAM's methodology for promoting geoeducation includes several key components aimed at effectively disseminating information, fostering engagement and maximising the impact of educational initiatives (**Figure 36**).

The first component is the education outreach policy. To ensure that efforts are targeted and effective, key stakeholders such as educators, students, local communities and tourists are identified. Information dissemination plays a crucial role, using various channels such as workshops, seminars, public lectures and information materials (brochures, posters, digital media) to raise awareness about geoeducation and the importance of geoheritage. Community outreach is also essential, organising events, geosite visits and interactive sessions to involve local people in understanding and appreciating their geological heritage.

Another important aspect is curriculum integration. The aim is to work with education authorities and curriculum developers on the integration of geo-education modules and activities into school curricula. The training of teachers is essential, and workshops and training sessions will be conducted to equip teachers with the skills they need to effectively integrate GEOAM and geo-education into their teaching practices.

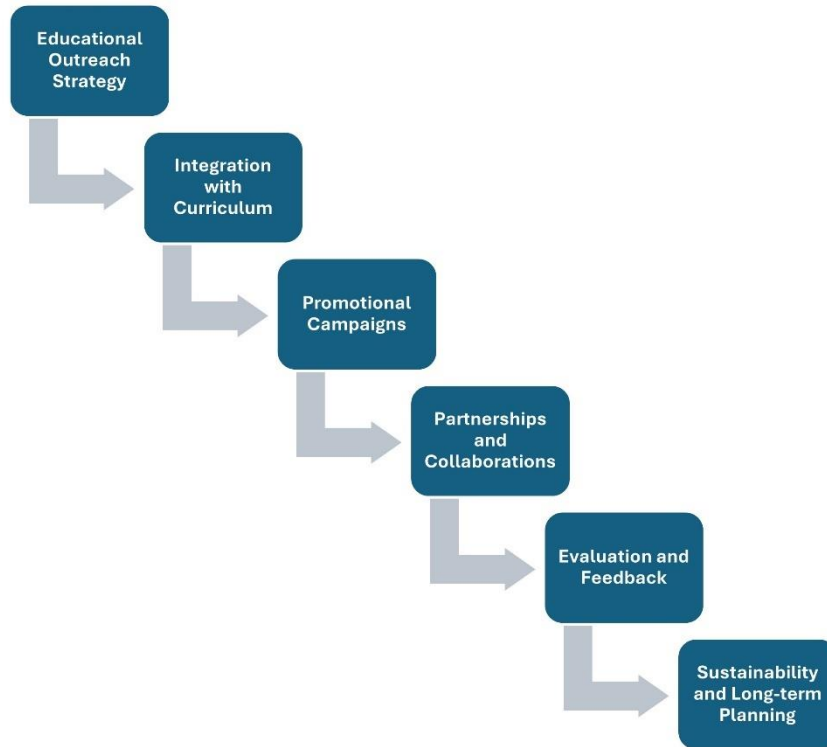
Promotional efforts also include advertising campaigns. Digital media campaigns use social media platforms, websites and online forums to promote GEOAM, share success stories and engage a wider audience. Traditional media such as local newspapers, radio and television are also used to reach different demographics and increase public awareness of geoeducation initiatives.

Partnerships and collaborations are of vital importance to extend the reach and impact of geo-education. Geoeducation activities are supported and promoted by establishing local partnerships with businesses, community organisations and environmental groups. Working with the tourism sector involves working with tour operators and agencies to integrate geoeducation into tourism packages, enhancing the visitor experience and promoting sustainable tourism practices.

To assess the effectiveness of promotional activities, evaluation and feedback mechanisms will be implemented. To gain insights and continuously improve initiatives, feedback forms, surveys and interviews will be used. The monitoring of outreach activities and the adjustment of strategies based on feedback and changing community needs will ensure sustained engagement and impact.

Finally, integral to the success of the outreach methodology is sustainability and long-term planning. Capacity building involves the development of resources and tools, such as educational materials and guides, to support ongoing geoeducation efforts beyond the initial promotion phase. Policy advocacy aims to influence decision-makers using research findings and community support to promote policies that support geo-education and sustainable development.

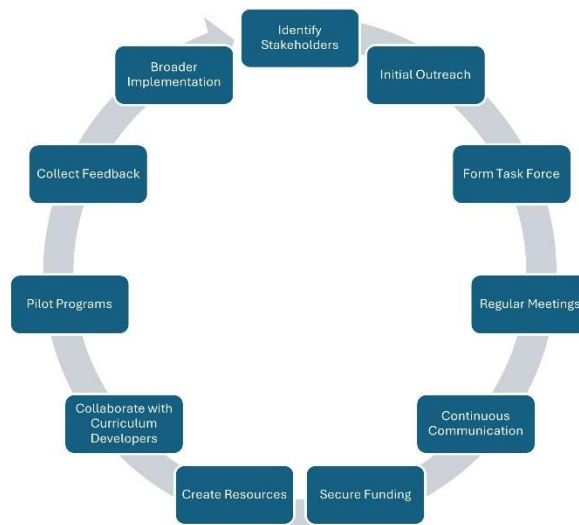
Through the implementation of these steps, GEOAM can effectively promote geoeducation, raise awareness of geoheritage and engage diverse stakeholders in the conservation and enhancement of geological resources.



**Figure 36.** The GEOAM as a promotion tool for geoeducation

### 6.3.1. The implementation of GEOAM

The implementation of GEOAM starts with several crucial preparation phases to ensure a successful rollout in schools (**Figure 37**).



**Figure 37.** A simplified flow diagram of the phases of implementing GEOAM in schools

The first step is the identification of stakeholders such as education authorities, school administrators, teachers, local government officials and community leaders. (Figure 38). The initial outreach involves organizing information sessions to explain the benefits of GEOAM. The positive impact on student learning should be emphasized.



**Figure 38.** The key factors of rising GEOAM's implementation

A task force is then formed to guide the process. It includes representatives from schools, geoscientists, education experts and local stakeholders. This group meets regularly to discuss progress. Challenges are addressed and strategies refined. Ongoing communication with stakeholders through newsletters, emails and social media keeps everyone informed and engaged. This builds trust and makes GEOAM a shared priority.

Securing funding involves exploring educational grants, NGOs, and private sponsors. Proposals emphasize GEOAM's benefits and expected outcomes to attract support. Creating user-friendly GEOAM manuals and digital resources for teachers is crucial, providing step-by-step instructions and lesson plans. GEOAM is integrated into existing courses and aligned with educational standards through collaboration with curriculum developers.

Pilot programs in selected schools test the integration of GEOAM. They identify best practices and gather feedback for adjustments before wider implementation. This phased approach ensures the effectiveness of GEOAM in different settings. GEOAM implementation improves geoeducation and fosters a deeper understanding of geological heritage among students by addressing these preparatory stages.

To empower educators, a comprehensive training program will be implemented. This will include workshops and seminars with hands-on exercises. Teachers will gain hands-on experience through field trips to local geosites. Mentorship programs will pair experienced educators with new teachers. This will create a supportive learning environment and accelerate professional growth. An online platform will provide tutorials, discussion forums and resources for ongoing teacher support (**Figures 39-42**).



**Figure 39.** The development of GEOAM through IT-tools

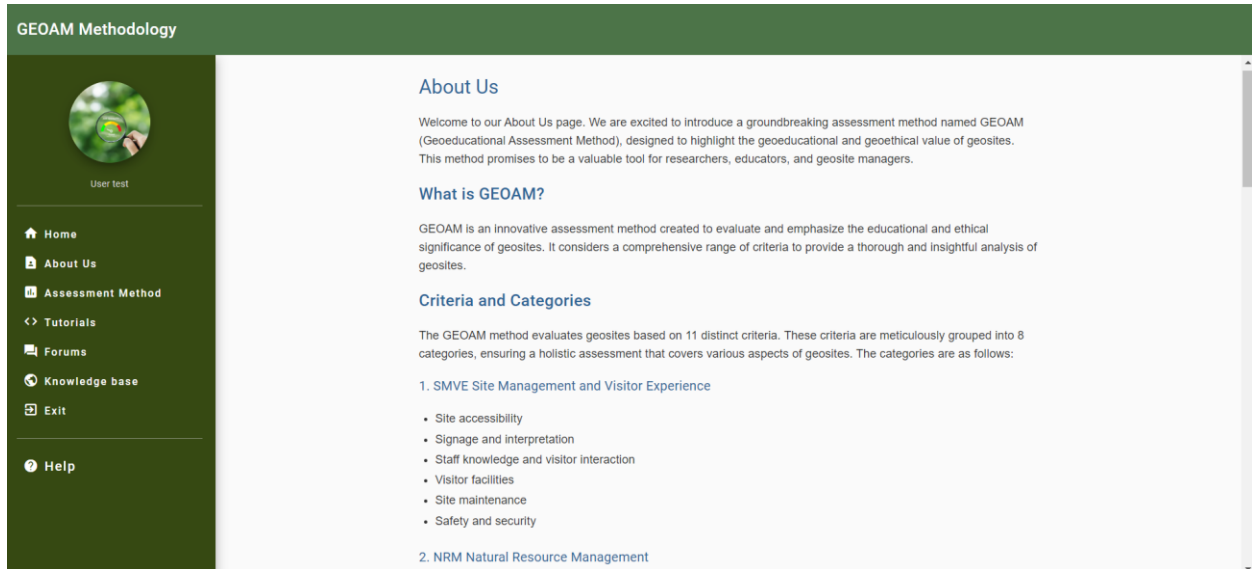
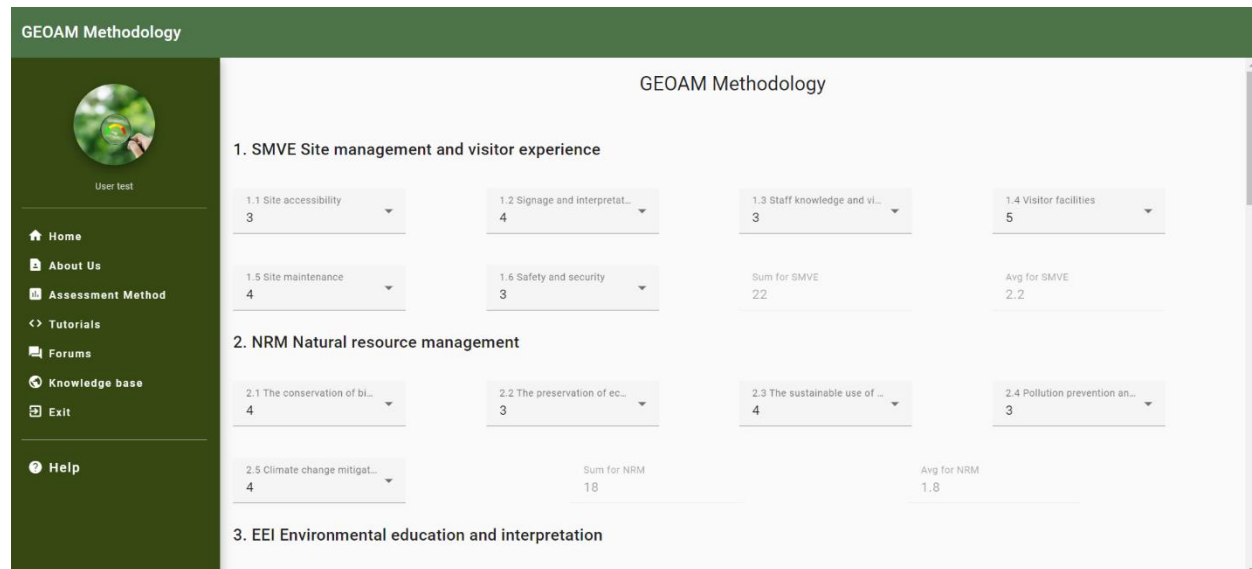


Figure 40. The online platform regarding to GEOAM methodology



Figure 41. The main characteristics of the platform



**Figure 42.** The possibility of assessment one geosite through the online platform

Educators will receive detailed lesson plans for incorporating GEOAM assessments and activities into their curriculum. These lesson plans consist of hands-on activities that encourage students to explore local geological sites, resulting in a better awareness of their geoenvironment. Creating student projects focused on appraising local geological monuments encourages experiential learning, improves their comprehension of geological topics, and fosters critical thinking abilities. **Appendix B** is a lesson plan that offers teachers with a systematic framework for effectively incorporating GEOAM into geography-geology lessons while involving children in hands-on education and critical thinking about the surrounding environment. Geoeducation groups will involve students in GEOAM-related activities after of school hours, such as field excursions, guest presentations, and research projects. These groups encourage collaboration and a continued interest in geology. Organizing competitions in which students exhibit their GEOAM analyses will increase participation and promote community knowledge of geological heritage. GEOAM's planned implementation of these activities improves the educational program and provides an engaging learning environment, creating a greater understanding of geological heritage among students.

### 6.3.2 Monitoring and Evaluation of GEOAM Implementation

To effectively monitor the implementation of GEOAM, it is important to have a clear set of key performance indicators (KPIs) and benchmarks. These measurables help track progress. Key indicators include (**Appendix C**)

- Number of schools and educators trained
- Student participation (measure student participation in geo-educational activities).
- Effective feedback mechanisms

GEOAM can be gradually extended to more schools and regions, based on lessons learned from ongoing evaluation and feedback.

### 6.3.3 Community Involvement: Engaging the Broader Public in GEOAM

It is of the utmost importance that the GEOAM initiative engages with the local community to ensure its success and sustainability. By disseminating information through public seminars and media outreach, and by encouraging involvement through collaborative projects and community events, GEOAM can establish a robust foundation of support and participation.

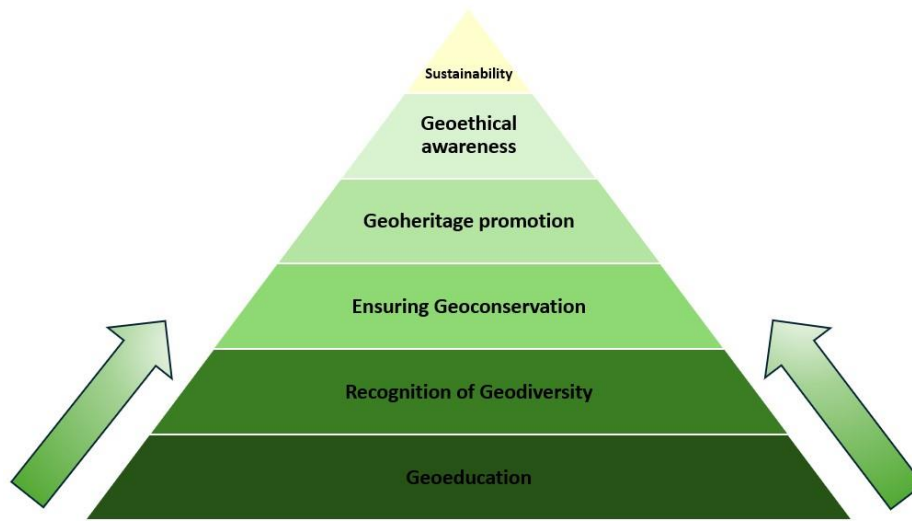
It is imperative that the community be educated about GEOAM and its benefits through public seminars. The seminars should elucidate the significance of geoscience education and the impact of GEOAM on students. Additionally, they should feature presentations from geoscientists, educational experts, and experienced teachers.

The effective utilisation of local media serves to extend the reach of GEOAM awareness campaigns. Such engagement can be achieved by initiating contact with local newspapers, radio and television stations with a view to sharing success stories and positive impacts associated with GEOAM. This may entail conducting interviews with teachers, students and parents who have benefited from GEOAM. Furthermore, social media can be utilised to disseminate information, engage with the community and keep the public informed about forthcoming events and milestones.

The formation of partnerships with local organisations can serve to enhance the impact of GEOAM initiatives. Potential strategic partners could include museums that would host educational exhibits and workshops, geological societies that would provide expert speakers and organise field trips, and environmental organisations that would assist with community outreach and engagement activities.

The organisation of community events serves to advance the cause of geoeducation and to engage the wider public in GEOAM activities. Such events may include guided tours of local geological sites and monuments, offering insights into their significance, activities that promote environmental stewardship and practical lessons in geo-conservation. They may also showcase student projects, GEOAM assessments and interactive exhibits in a festive, informative environment.

Through these efforts, GEOAM can foster a deeper understanding and appreciation of geological heritage, promoting a culture of geo-ethical awareness and sustainable development within the community (**Figure 43**).



**Figure 43.** Contribution of GEOAM through geoeducational activities

#### 6.3.4 Main Challenges: Addressing Barriers to the Implementation of GEOAM

A significant obstacle is the reluctance of educators and administrators to embrace change, particularly when it comes to the curriculum. To surmount this obstacle, it is imperative to elucidate the advantages of GEOAM in a perspicuous manner and to implement pilot programs to exemplify its favourable impact on student learning.

Securing adequate funding and resources also represents a considerable challenge. To address this issue, it would be prudent to consider novel fundraising strategies, such as crowdfunding and community events, in conjunction with forging partnerships with local businesses for sponsorship and collaborating with local organisations, museums, and environmental groups for in-kind resources.

It can prove challenging to guarantee that all teachers receive sufficient training and ongoing professional development, given the constraints of time and resources. To address this issue, a comprehensive training plan should be developed, comprising initial workshops and ongoing support. Furthermore, online platforms should be employed for the purposes of continuous professional development, offering tutorials, webinars, and forums.

The integration of GEOAM into the existing curriculum must be meticulously planned to prevent overwhelming teachers. To facilitate this process, it is essential to collaborate with curriculum developers to align GEOAM with educational standards, to create flexible and adaptable lesson plans, to provide clear guidelines and resources for teachers, and to utilize pilot programs in order to identify challenges and improve integration.

Ultimately, it is essential to maintain long-term community interest in GEOAM initiatives. To this end, awareness campaigns and public seminars should be conducted, success stories and benefits should be shared through local media and social media, community events such as geosite tours and educational fairs should be organised, and collaboration with local organisations should be sought to foster a sense of ownership and ongoing interest.

By addressing these challenges with strategic planning and community involvement, the implementation of GEOAM can be more effective and sustainable.

## Chapter 7: Assessing Geoeducational Potential: Results, Challenges, and Advancements with GEOAM

In this chapter, we delve into the assessment of geoeducational potential across the three distinct geographical locations: Kalymnos, Nisyros, and Samos. Through the lens of three different assessment methods – the General-Purpose Model (G-P Method), the Modified Geoheritage Assessment Model (M-GAM Method), and the newly introduced GEOAM – we explore the unique educational opportunities presented by each site. Our aim is to provide a comprehensive analysis of the results obtained from applying these methods, highlighting their strengths, limitations, and implications for geoeducational planning and management. By conducting a comparative analysis of the outcomes derived from each method, we seek to elucidate the advancements, challenges, and prospects in assessing geoeducational potential, paving the way for informed decision-making and sustainable development in geotourism and education.

### 7.1. Kalymnos island

#### 7.1.1. The General-Purpose Model—G-P Method

To finalize the quantification process for assessing the potential utilization at scientific, educational, and tourist levels, we initially consider specific criteria along with their corresponding weightings.

Upon initial examination of both the scientific and educational criteria, it becomes evident that the geological areas on the island exhibit a high level of interest and fulfill the entire spectrum of criteria. In fact, they conform to stringent specifications, setting the stage for their potential utilization in the future, particularly in a more structured manner for educational and scientific purposes. Upon reviewing the results of the evaluation, particularly in the context of the scientific value (SV) (as seen in **Table 10**), it's apparent that three study areas receive high scores (>301) (**Lima, 2008**). Notably, the climbing fields (GS.K7 and GS.K8) and the Sikati cave (GS.K6) attained a final score of 325. This is primarily attributed to the rarity of these specific sites and the extent to which they represent the geological features present. In contrast, the Choiromantres cave (GS.K3) receives the lowest score (<200). All other locations demonstrate moderate scores (201–300), ranging from 210 to 270.

**Table 10.** Quantitative evaluation of geosites for scientific value (SV) according to G-PM.

Scientific Criteria	Weight	GS.K1	GS.K2	GS.K3	GS.K4	GS.K5	GS.K6	GS.K7	GSK.K8
Representativeness	30	2	4	2	4	4	4	4	4
Key locality	20	1	1	1	1	1	1	1	1
Scientific knowledge	5	1	1	1	1	1	1	1	1
Integrity	15	4	4	1	4	4	4	4	4

Geological diversity	5	2	2	1	2	2	4	4	4
Rarity	15	1	1	1	1	1	4	4	4
Use limitations	10	4	4	4	4	1	4	4	4
Total Score		210	270	160	270	240	325	325	325
		Moderate	Moderate	Low	Moderate	Moderate	High	High	High
		≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)							

Regarding the potential for educational use (PEU, as shown in **Table 11**), it is apparent that four caves receive high scores, while two other caves obtain moderate scores. Specifically, the Choiromantes cave (GS.K3) lacks significant geological diversity, and it's also less accessible to the public. Additionally, the main part of the Stimenia cave (GS.K5) isn't easily reached. Conversely, the other sites achieve high scores and are well-suited for educational purposes. It's worth noting that both climbing fields (GS.K7 and GS.K8) also receive relatively favorable scores. Moreover, nearly all the sites are intertwined with other values, including historical and cultural aspects, among others.

**Table 11.** Quantitative evaluation of geosites for educational potential use (PEU) according to G-PM.

Educational Criteria	Weight	GS.K1	GS.K2	GS.K3	GS.K4	GS.K5	GS.K6	GS.K7	GSK.K8
Vulnerability	10	4	4	4	4	4	4	4	4
Accessibility	10	3	4	4	4	3	3	4	4
Use limitations	5	3	4	4	4	1	2	4	4
Safety	10	3	4	1	3	2	2	4	4
Logistics	5	4	4	2	4	4	4	4	4
Density of population	5	4	4	4	4	4	4	4	4
Association with other values	5	4	4	4	2	4	2	2	2
Scenery	5	2	2	2	2	2	2	4	4
Uniqueness	5	3	2	2	2	2	2	2	2
Observation conditions	10	4	4	2	4	4	4	4	4
Didactic potential	20	3	3	3	3	3	3	3	3
Geological diversity	10	2	2	1	2	2	4	4	4
Total score		320	340	270	320	295	310	360	360
		High	High	Moderate	High	Moderate	High	High	High
		≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)							

Tourism aspects play a crucial role in advancing and enhancing geotourism. When assessing the potential for touristic use (PTU, as presented in **Table 12**) of the studied regions, it's evident that all locations obtain high scores. Notably, the climbing fields (GS.K7 and GS.K8) achieve relatively high scores, primarily owing to their distinct and picturesque landscapes. Moreover, the caves receive high scores across most factors. The sole unfavorable aspect in this table pertains to the economic status of the residents in the area.

**Table 12.** Quantitative evaluation of geosites for tourism potential use (PTU) according to G-PM.

Touristic Criteria	Weight	GS.K1	GS.K2	GS.K3	GS.K4	GS.K5	GS.K6	GS.K7	GSK.K8
Vulnerability	10	4	4	4	4	4	4	4	4
Accessibility	10	3	4	4	4	3	3	4	4
Use limitations	5	3	4	4	4	1	2	4	4
Safety	10	3	4	1	3	2	2	4	4

Logistics	5	4	4	2	4	4	4	4	4
Density of population	5	4	4	4	4	4	4	4	4
Association with other values	5	4	4	4	2	4	2	2	2
Scenery	15	2	2	2	2	2	2	4	4
Uniqueness	10	3	2	2	2	2	2	2	2
Observation conditions	5	4	4	2	4	4	4	4	4
Interpretative potential	10	4	4	3	4	4	4	4	4
Economic level	5	1	1	1	1	1	1	1	1
Proximity of recreational areas	5	4	4	4	4	4	4	4	4
Total Score		320 High	335 High	275 Moderate	315 High	290 Moderate	285 Moderate	355 High	355 High

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)

It is of equal significance to investigate and assess the level of degradation risk, in line with **Brilha's 2016** degradation criteria. To facilitate this evaluation, the following table has been compiled (**Table 13**). Upon reviewing the table's findings, it becomes evident that the climbing fields (GS.K7 and GS.K8), which are relatively close to the island's main road network, exhibit a higher degree of vulnerability, resulting in relatively high scores. In contrast, the Daskalio cave (GS.K1), accessible only by sea, receives the lowest score. Additionally, it's noteworthy that not all sites register high scores, which represents a notable positive aspect for their more organized and prudent utilization.

**Table 13.** Degradation risk evaluation of geosites according to G-PM.

Degradation Risk Criteria	Weight	GS.K1	GS.K2	GS.K3	GS.K4	GS.K5	GS.K6	GS.K7	GSK.K8
Deterioration of geological features	35	1	1	3	1	1	1	1	1
Proximity to areas/activities with potential to cause degradation	20	2	2	3	2	2	1	2	2
Legal protection	20	2	1	2	1	2	3	4	4
Accessibility	15	1	3	3	4	4	3	3	3
Density of population	10	4	4	4	4	4	4	4	4
Total score		170 Low	180 Low	290 Moderate	195 Low	215 Moderate	200 Low	240 Moderate	240 Moderate

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008; Brilha, 2016)

### 7.1.2. The M-GAM Method

The results of the M-GAM method, as applied in Kalymnos, are shown in **Tables 14-16**. The main values consist of twelve criteria, while the additional values consist of seventeen criteria.

**Table 14.** Implementation of M-GAM method in Kalymnos geosites 1 up to 4 (Tomić & Božić, 2014; Božić & Tomić, 2015)

	Values given by experts	Total value (with Im factor)
--	-------------------------	------------------------------

	GS.K1	GS.K2	GS.K3	GS.K4	Im	GS.K1	GS.K2	GS.K3	GS.K4
<b>Main Values (MV)</b>									
Scientific/Educational value (VSE)									
1.Rarity	0.25	0.25	0.25	0.25	0.89	0.2225	0.2225	0.2225	0.2225
2.Representativeness	0.75	0.75	0.25	0.75	0.79	0.5925	0.5925	0.1975	0.5925
3.Knowledge of scientific issues	0.75	0.75	0.25	0.75	0.45	0.3375	0.3375	0.1125	0.3375
4.Level of interpretation	0.75	0.75	0.5	0.75	0.85	0.6375	0.6375	0.425	0.6375
<b>Scenic/Aesthetic (VSA)</b>									
5. Viewpoints	0.5	0.5	0.25	0.25	0.79	0.395	0.395	0.1975	0.1975
6. Surface	0.5	0.5	0	0.5	0.54	0.27	0.27	0	0.27
7. Surrounding landscape and nature	0.5	0.5	0.5	0.5	0.95	0.475	0.475	0.475	0.475
8. Environmental fitting of sites	1	1	0.5	1	0.68	0.68	0.68	0.34	0.68
<b>Protection (VPr)</b>									
9. Current condition	0.75	0.75	0.25	0.75	0.83	0.6225	0.6225	0.2075	0.6225
10. Protection level	1	1	0	0.5	0.76	0.76	0.76	0	0.38
11. Vulnerability	0.5	0.5	0	0.5	0.58	0.29	0.29	0	0.29
12. Suitable number of visitors	0.5	0.5	0.25	0.25	0.42	0.21	0.21	0.105	0.105
<b>Additional values (AV)</b>									
<b>Functional values (VFn)</b>									
13. Accessibility	0.5	0.5	0.5	0.25	0.75	0.375	0.375	0.375	0.1875
14. Additional natural values	0.75	0.75	0.25	0.5	0.71	0.5325	0.5325	0.1775	0.355
15. Additional anthropogenic values	0.75	0.75	0.25	0.5	0.7	0.525	0.525	0.175	0.35
16. Vicinity of emissive centers	0.75	0.75	0.75	0.75	0.48	0.36	0.36	0.36	0.36
17. Vicinity of important road network	0.5	0.5	0.5	0.5	0.62	0.31	0.31	0.31	0.31
18. Additional functional values	0.5	0.5	0.25	0.5	0.59	0.295	0.295	0.1475	0.295
<b>Touristic values (VTr)</b>									
19. Promotion	0.5	0.5	0.25	1	0.85	0.425	0.425	0.2125	0.85
20. Organized visits	0.25	0.25	0	0.25	0.56	0.14	0.14	0	0.14
21. Vicinity of visitor's centers	0.75	0.75	0.75	0.75	0.87	0.6525	0.6525	0.6525	0.6525
22. Interpretative panels	0.25	0.25	0	0.25	0.81	0.2025	0.2025	0	0.2025

23. Number of visitors	0.25	0.25	0.25	0.25	0.43	0.1075	0.1075	0.1075	0.1075
24. Tourism infrastructure	0.5	0.5	0.5	0.5	0.73	0.365	0.365	0.365	0.365
25. Tour guide service	0.5	0.5	0.25	0.25	0.87	0.435	0.435	0.2175	0.2175
26. Hostelry service	1	1	1	1	0.73	0.73	0.73	0.73	0.73
27. Restaurant service	0.75	0.75	0.75	0.75	0.78	0.585	0.585	0.585	0.585

**Table 15.** Implementation of M-GAM method in Kalymnos geosites 5 up to 8 (Tomić & Božić, 2014; Božić & Tomić, 2015)

	Values given by experts					Im	Total value (with Im factor)			
	GS.K5	GS.K6	GS.K7	GS.K8	GS.K5		GS.K6	GS.K7	GS.K8	
<b>Main Values (MV)</b>										
Scientific/Educational value (VSE)										
1. Rarity	0.25	0.25	0.75	0.75	0.89	0.2225	0.2225	0.6675	0.6675	
2. Representativeness	0.5	0.5	0.75	0.75	0.79	0.395	0.395	0.5925	0.5925	
3. Knowledge of scientific issues	0.5	0.5	0.75	0.75	0.45	0.225	0.225	0.3375	0.3375	
4. Level of interpretation	0.75	0.75	0.75	0.75	0.85	0.6375	0.6375	0.6375	0.6375	
Scenic/Aesthetic (VSA)										
5. Viewpoints	0.25	0.5	0.75	0.75	0.79	0.1975	0.395	0.5925	0.5925	
6. Surface	0.5	0.5	1	1	0.54	0.27	0.27	0.54	0.54	
7. Surrounding landscape and nature	0.5	0.5	0.75	0.75	0.95	0.475	0.475	0.7125	0.7125	
8. Environmental fitting of sites	1	1	1	1	0.68	0.68	0.68	0.68	0.68	
<b>Protection (VPr)</b>										
9. Current condition	0.75	0.5	0.75	0.75	0.83	0.6225	0.415	0.6225	0.6225	
10. Protection level	0.25	0.25	0.75	0.75	0.76	0.19	0.19	0.57	0.57	
11. Vulnerability	0.5	0.5	0.5	0.5	0.58	0.29	0.29	0.29	0.29	
12. Suitable number of visitors	0.25	0.25	1	0.75	0.42	0.105	0.105	0.42	0.315	
<b>Additional values (AV)</b>										
<b>Functional values (VFn)</b>										
13. Accessibility	0.25	0.25	0.75	0.25	0.75	0.1875	0.1875	0.5625	0.1875	
14. Additional natural values	0.5	0.25	0.75	0.75	0.71	0.355	0.1775	0.5325	0.5325	
15. Additional anthropogenic values	0.5	0.25	0.75	0.75	0.7	0.35	0.175	0.525	0.525	
16. Vicinity of emissive centers	0.75	0.75	0.75	0.75	0.48	0.36	0.36	0.36	0.36	
17. Vicinity of important road network	0.5	0.5	0.5	0.5	0.62	0.31	0.31	0.31	0.31	
18. Additional functional values	0.5	0.5	0.75	0.75	0.59	0.295	0.295	0.4425	0.4425	

<b>Touristic values (VTr)</b>									
19. Promotion	0.5	0.5	1	1	0.85	0.425	0.425	0.85	0.85
20. Organized visits	0.25	0.5	1	1	0.56	0.14	0.28	0.56	0.56
21. Vicinity of visitor's centers	0.75	0.75	0.75	0.75	0.87	0.6525	0.6525	0.6525	0.6525
22. Interpretative panels	0	0	0.5	0.5	0.81	0	0	0.405	0.405
23. Number of visitors	0.25	0.25	0.25	0.25	0.43	0.1075	0.1075	0.1075	0.1075
24. Tourism infrastructure	0.5	0.5	0.5	0.5	0.73	0.365	0.365	0.365	0.365
25. Tour guide service	0.25	0.5	0.75	0.75	0.87	0.2175	0.435	0.6525	0.6525
26. Hostelry service	1	1	1	1	0.73	0.73	0.73	0.73	0.73
27. Restaurant service	0.75	0.75	0.75	0.75	0.78	0.585	0.585	0.585	0.585

Based on the table provided, the values given by experts and the total values with the Im factor for each criterion in the M-GAM method can be analyzed. For the Main Values (MV) under Scientific/Educational Value (VSE), all eight geological monuments show consistent scores for criteria like rarity (except for GS.K5 and GS. K6) and level of interpretation, but GS.K3 generally scores lower compared to the other sites. This is evident in representativeness and knowledge of scientific issues, where GS.K3's scores are significantly less, affecting its overall value. Similarly, for Scenic/Aesthetic Value (VSA), while most sites score evenly, GS.K3 tends to have lower scores, particularly in viewpoints and surface criteria, leading to lower total values after applying the Im factor.

When it comes to Protection (VPr) values, GS.K3 consistently scores lower across criteria such as current condition and protection level, while the other sites maintain higher scores. The Im factor's application highlights these disparities further, indicating that GS.K3 is less favorable in terms of its protection values. This trend continues in criteria like vulnerability and suitable number of visitors, where GS.K3's scores remain the lowest among the sites, emphasizing its relative vulnerability and lower capacity to accommodate visitors effectively.

For Additional Values (AV), under Functional Values (VF<sub>n</sub>), and Touristic Values (VTr), the scoring disparities continue. GS.K3, GS.K5, GS.K6 and GS.K8 score lower than the others geosites in aspects like accessibility. Furthermore GS.K3 presents low scores in the criteria such as: additional natural and anthropogenic values, and vicinity of emissive centers. This pattern is also seen in touristic criteria like promotion, organized visits, and interpretative panels, where GS.K3's scores are notably lower. Despite this, all sites show uniform scores for criteria like vicinity of visitor's centers, number of visitors, tourism infrastructure, and services such as hostelry and restaurant, leading to uniform total values after applying the Im factor.

**Table 16.** Results of the application of the M-GAM method in Kalymnos.

<b>Geosite</b>	<b>Main values</b>		<b>Additional values</b>		<b>Field area</b>
	VSE+VSA+VPr	SUM	VF <sub>n</sub> +VTr	SUM	

GS.K1	1.79+1.82+1.8825	5.4925	2.3975+3.6425	6.04	Z22
GS.K2	1.79+1.82+1.8825	5.4925	2.3975+3.6425	6.04	Z22
GS.K3	0.9575+1.0125+0.3125	2.2825	1.545+2.87	4.415	Z11
GS.K4	1.79+1.6225+1.3975	4.81	1.8575+3.85	5.7075	Z22
GS.K5	1.48+1.6225+1.2075	4.31	1.8575+3.225	5.08	Z22
GS.K6	1.48+1.82+1	4.3	1.505+3.58	5.085	Z22
GS.K7	2.235+2.525+1.9025	6.6625	2.7325+4.9075	7.64	Z22
GS.K8	2.235+2.525+1.7975	6.5575	2.3575+4.9075	7.265	Z22

**Table 41** presents the results of the application of the M-GAM method in Kalymnos, summarizing both the main and additional values for each geosite. For the main values, which include Scientific/Educational value (VSE), Scenic/Aesthetic value (VSA), and Protection (VPr), geosites GS.K1, GS.K2, GS.K4, GS.K5, GS.K6, GS.K7, and GS.K8 generally score higher, with GS.K7 and GS.K8 leading with scores of 6.6625 and 6.5575, respectively. Conversely, GS.K3 scores significantly lower with a total of 2.2825, highlighting its lower performance in these main categories.

Regarding the additional values, which encompass Functional values (VF<sub>n</sub>) and Touristic values (VTr), the trend remains consistent with geosites GS.K7 and GS.K8 achieving the highest scores of 7.64 and 7.265, respectively. GS.K1 and GS.K2 follow with identical scores of 6.04, while GS.K3 again lags behind with a total score of 4.415. These results underline the relative strength of GS.K7 and GS.K8 in both functional and touristic attributes.

The field area designation indicates that most geosites (GS.K1, GS.K2, GS.K4, GS.K5, GS.K6, GS.K7, GS.K8) belong to field Z22, which includes areas with comparable geological features and higher overall scores. In contrast, GS.K3 is placed in field Z11, reflecting its lower total scores and indicating different geological characteristics or lesser value across the evaluated criteria.

**Diagram 4** demonstrates the definitive results of the method. In these results, field Z22 includes seven of the eight areas analyzed. These seven areas show comparable values and characteristics in terms of geological features. Conversely, field Z11 includes one area that achieves the lowest score in comparison to the other seven.

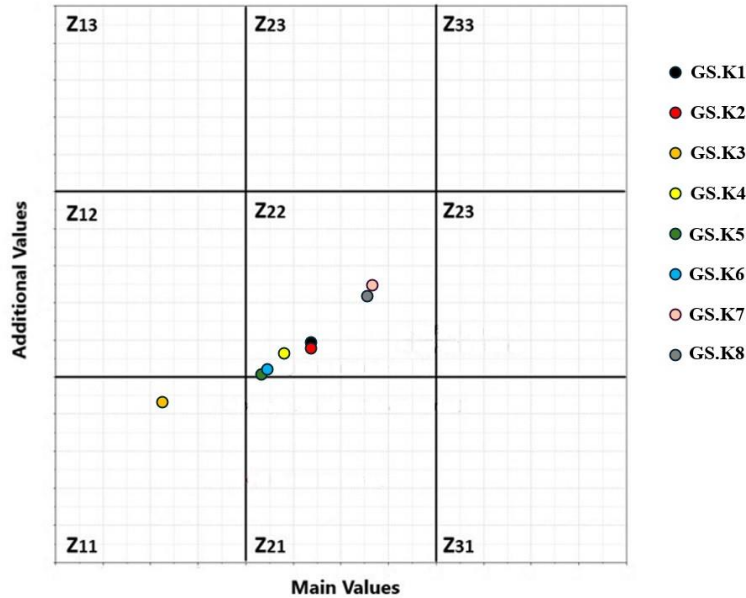


Diagram 4. The display of results from the M-GAM method.

### 7.1.3 The GEOAM

Tables 17 to 24 present detailed scoring systems for the geosites of Kalymnos across various criteria.

Table 8, which focuses on Site Management and Visitor Experience (SMVE), shows that geosites GS.K2, GS.K4, GS.K7, and GS.K8 consistently score higher, with an average of 4.66, indicating superior site accessibility, signage, visitor interaction, and maintenance. In contrast, GS.K3 and GS.K5 have lower averages of 2.66 and 2.50, respectively, pointing to areas needing improvement, particularly in signage, visitor interaction, and site maintenance.

Table 17. Scoring system in the geomorphosites of Kalymnos on SMVE

SMVE—Site Management and Visitor Experience								
Subcriteria	GS.K1	GS.K2	GS.K3	GSK.4	GS.K5	GS.K6	GS.K7	GS.K8
Site accessibility	3	5	5	5	3	3	5	5
Signage and interpretation	2	5	2	5	2	3	5	5
Staff knowledge and visitor interaction	2	5	2	5	2	2	5	5
Visitor facilities	3	5	3	5	3	3	5	5
Site maintenance	3	5	2	5	3	3	5	5
Safety and security	3	3	2	3	2	3	3	3
Average	2.66	4.66	2.66	4.66	2.50	2.83	4.66	4.66

Table 18 evaluates Natural Resource Management (NRM), where GS.K2, GS.K4, GS.K5, GS.K6, GS.K7, and GS.K8 all have an average score of 3.40, demonstrating strong performance in ecosystem preservation, sustainable resource use, and pollution control. GS.K3, however, has a

lower average score of 2.00, highlighting deficiencies in preservation and sustainable practices. This table emphasizes the need for GS.K3 to enhance its conservation and sustainability efforts.

**Table 18.** Scoring system in the geomorphosites of Kalymnos on NRM

<b>NRM—Natural Resource Management</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Conservation of biodiversity	3	3	3	3	3	3	3	3
Preservation of ecosystems	3	4	1	4	4	4	4	4
Sustainable use of natural resources	3	4	2	4	4	4	4	4
Pollution prevention and control	4	4	2	4	4	4	4	4
Climate change mitigation and adaptation	2	2	2	2	2	2	2	2
Average	3.00	3.40	2.00	3.40	3.40	3.40	3.40	3.40

**Tables 19** through 24 cover various other aspects of site evaluation, such as Environmental Education and Interpretation (EEI), Cultural and Historical Significance (CHS), Community Involvement and Engagement (CIE), Geoethics (GE), Economic Viability (EV), and Sustainable Development (SD). In EEI, GS.K2, GS.K4, GS.K7, and GS.K8 score better, averaging around 2.20 and 2.00, suggesting effective educational practices and staff availability. CHS shows that GS.K2 leads with an average of 4.50, underscoring its significant cultural and historical value. CIE highlights GS.K7 and GS.K8 with top scores of 4.75, reflecting robust community engagement. For GE, GS.K2 and GS.K4 achieve the highest averages (4.00 and 3.60), indicating good geoethical practices. EV scores reveal GS.K7 and GS.K8 as economically viable with averages of 4.60, and SD shows GS.K2, GS.K7, and GS.K8 leading with averages of 3.33, indicating strong sustainable practices. Overall, GS.K7 and GS.K8 consistently perform well across all criteria, positioning them as exemplary sites in Kalymnos.

**Table 19.** Scoring system in the geomorphosites of Kalymnos on EEI

<b>EEI—Environmental Education and Interpretation</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Presence of interpretive signage or exhibits	1	1	1	1	1	1	1	1
Availability of trained interpretive staff or volunteers	2	3	1	3	2	2	3	3
Integration of environmental education and interpretation	2	4	2	3	2	2	3	3
Inclusion of interactive and hands-on activities	2	2	1	3	2	2	2	2
Incorporation of environmentally friendly practices	1	1	1	1	1	1	1	1
Average	1.60	2.20	1.20	2.20	1.60	1.60	2.00	2.00

**Table 20.** Scoring system in the geomorphosites of Kalymnos on CHS

<b>CHS—Cultural and Historical Significance</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Historical significance	5	5	5	3	3	2	2	2
Cultural significance	5	5	5	3	2	2	2	2
Interpretation and education	2	5	2	3	2	2	2	2
Cultural diversity and inclusivity	2	3	1	2	2	2	2	2

Average	3.50	4.50	3.25	2.75	2.25	2.00	2.00	2.00
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**Table 21.** Scoring system in the geomorphosites of Kalymnos on CIE

<b>CIE—Community Involvement and Engagement</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Stakeholder participation	3	3	1	3	2	2	5	5
Cultural sensitivity	2	4	2	3	2	2	4	4
Community benefits	3	5	2	4	3	3	5	5
Outreach and communication	3	5	2	4	2	2	5	5
Average	2.75	4.25	1.75	3.50	2.25	2.25	4.75	4.75

**Table 22.** Scoring system in the geomorphosites of Kalymnos on GE

<b>GE—Geoethics</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Environmental impact	5	5	2	5	5	5	4	4
Cultural heritage	3	4	2	4	3	3	3	3
Social responsibility	3	4	2	3	3	3	3	3
Transparency and accountability	2	4	2	3	2	2	4	4
Professional conduct	3	3	2	3	2	2	4	4
Average	3.20	4.00	2.00	3.60	3.00	3.00	3.60	3.60

**Table 23.** Scoring system in the geomorphosites of Kalymnos on EV

<b>EV—Economic Viability</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Tourist revenue potential	4	3	2	4	3	2	5	5
Local economic impact	4	4	2	3	3	3	5	5
Sustainability of economic benefits	3	4	3	3	3	3	4	4
Cost-effectiveness of management	3	4	2	3	3	3	4	4
Innovative economic models	3	5	2	3	3	3	5	5
Average	3.40	4.00	2.20	3.20	3.00	2.80	4.60	4.60

**Table 24.** Scoring system in the geomorphosites of Kalymnos on SD

<b>SD—Sustainable Development</b>								
<b>Subcriteria</b>	<b>GS.K1</b>	<b>GS.K2</b>	<b>GS.K3</b>	<b>GS.K4</b>	<b>GS.K5</b>	<b>GS.K6</b>	<b>GS.K7</b>	<b>GS.K8</b>
Resource efficiency	3	4	3	4	4	4	4	4
Waste management	3	3	2	3	3	3	3	3
Biodiversity conservation	3	3	3	3	3	3	3	3
Social and economic impacts	4	5	2	4	3	3	5	5
Climate change adaptation	1	1	1	1	1	1	1	1
Cultural heritage preservation	3	4	3	4	3	3	4	4
Average	2.83	3.33	2.33	3.16	2.83	2.83	3.33	3.33

**Table 25** presents the scoring system for the geosites of Kalymnos according to the GEOAM method, with criteria weighted and final scores calculated for each geosite. The criteria include Site Management and Visitor Experience (SMVE), Natural Resource Management

(NRM), Environmental Education and Interpretation (EEI), Cultural and Historical Significance (CHS), Geoethics (GE), Economic Viability (EV), Community Involvement and Engagement (CIE), and Sustainable Development (SD). Each criterion has a specific weight, contributing to the final score for each geosite.

For SMVE, which has a weight of 10%, GS.K2, GS.K4, GS.K7, and GS.K8 score the highest with 4.66, reflecting strong site management and visitor experience. GS.K3 and GS.K5 have lower scores, indicating areas for improvement. NRM, also weighted at 10%, shows consistent scores across most geosites, with GS.K2, GS.K4, GS.K5, GS.K6, GS.K7, and GS.K8 scoring 3.40, while GS.K3 lags behind with 2.00, suggesting weaker natural resource management.

EEI, the most heavily weighted criterion at 30%, shows GS.K2 and GS.K4 leading with scores of 2.20, while GS.K3 has the lowest score of 1.20. This highlights the importance of environmental education and interpretation in the overall assessment. For CHS, weighted at 10%, GS.K2 excels with 4.50, indicating significant cultural and historical value, while other geosites vary in their scores.

Geoethics (GE), with a 20% weight, sees GS.K2 and GS.K7 scoring high at 4.25 and 4.75 respectively, underscoring their adherence to geoethical practices. EV and CIE, both weighted at 5%, show GS.K7 and GS.K8 performing well in terms of economic viability and community engagement, with scores of 3.60 and 4.60 respectively. Lastly, SD, with a 10% weight, indicates GS.K2, GS.K7,

The final scores, calculated based on the weighted criteria, range from 1.934 for GS.K3 to 3.499 for GS.K2. Most geosites fall within the "High Implementation" category ( $3 \leq \text{High Implementation} < 4$ ), with GS.K2, GS.K4, GS.K6, GS.K7, and GS.K8 achieving this classification. GS.K3, with a score of 1.934, is characterized as "Low Implementation" ( $1 < \text{Low Implementation} < 2$ ), indicating significant areas for improvement. GS.K1 and GS.K5 fall into the "Medium Implementation" category ( $2 \leq \text{Medium Implementation} < 3$ ), showing moderate performance across the criteria.

**Table 25.** Scoring system for the geosites of Kaymnos and the final scores according GEOAM.

Criteria	Weight	GS.K1	GS.K2	GS.K3	GS.K4	GS.K5	GS.K6	GS.K7	GS.K8
SMVE	10%	2.66	4.66	2.66	4.66	2.50	2.83	4.66	4.66
NRM	10%	3.00	3.40	2.00	3.40	3.40	3.40	3.40	3.40
EEI	30%	1.60	2.20	1.20	2.20	1.60	1.60	2.00	2.00
CHS	10%	3.50	4.50	3.25	2.75	2.25	2.00	2.00	2.00
GE	20%	2.75	4.25	1.75	3.50	2.25	2.25	4.75	4.75
EV	5%	3.20	4.00	2.00	3.60	3.00	3.00	3.60	3.60
CIE	5%	3.40	4.00	2.20	3.20	3.00	2.80	4.60	4.60
SD	10%	2.83	3.33	2.23	3.16	2.83	2.83	3.33	3.33
Final Score		2.559	3.499	1.934	3.097	2.328	3.138	3.299	3.299
Characterization of score		MI	HI	LI	HI	MI	HI	HI	HI

1<Low Implementation<2; 2≤Medium Implementation<3; 3≤High Implementation<4; 4≤Very High Implementation<4.5 From 4.5 up: Extremely High Implementation

The assessment results of table 50 show that the geomorphosites on Kalymnos have a relatively high geoeucational interest. The use of the GEOAM method tailored to the specific conditions of Kalymnos highlights significant geological phenomena and characteristics across the island. According to the GEOAM criteria, these sites demonstrate considerable geological importance, making them ideal for various educational programs and projects. Among the eight geomorphosites evaluated on Kalymnos, four scored high, three received a medium score, and one had a low score. This distinct variation underscores the presence of notable geological features on the island, offering many opportunities to showcase the importance of geoheritage through different geoeucational activities and efforts.

## 7.2. Nisyros island

### 7.2.1. The General-Purpose Model—G-P Method

The results of this method are shown in **Tables 26-29**. Table 26 evaluates the scientific value (SV) of geosites based on criteria such as representativeness, key locality, scientific knowledge, integrity, geological diversity, rarity, and use limitations. Each criterion is assigned a weight, and the scores for geosites GS.N1 through GS.N5 are provided. GS.N1 and GS.N2 scored high with totals of 315, indicating their significant scientific value, while GS.N3, GS.N4, and GS.N5 scored moderate with totals of 250, 230, and 250, respectively. According to **Lima (2008)**, scores greater than 301 indicate high scientific value, while scores between 201 and 300 denote moderate value.

**Table 26.** Quantitative evaluation of geosites for scientific value (SV)

Scientific criteria	Weight	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
Representativeness	30	3	3	2	2	2
Key locality	20	2	2	2	1	2
Scientific knowledge	5	4	4	2	2	2
Integrity	15	4	4	4	4	4
Geological diversity	5	4	4	2	2	2
Rarity	15	3	3	2	2	2
Use limitations	10	4	4	4	4	4
Total Score		315 High	315 High	250 Moderate	230 Moderate	250 Moderate

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008).

**Table 27** assesses the educational potential use (PEU) of the geosites, evaluating criteria such as vulnerability, accessibility, use limitations, safety, logistics, population density, association with other values, scenery, uniqueness, observation conditions, didactic potential, and geological diversity. GS.N1 and GS.N2 received high scores of 385 and 370, respectively, highlighting their strong educational potential. GS.N3 and GS.N5 also scored high with 315 and 320, while GS.N4

scored moderate with 285. Scores above 301 are considered high, and those between 201 and 300 are moderate.

**Table 27.** Quantitative evaluation of geosites for educational potential use (PEU)

Educational criteria	Weight	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
Vulnerability	10	4	4	4	4	4
Accessibility	10	4	4	4	1	4
Use limitations	5	4	4	4	4	4
Safety	10	3	3	3	3	3
Logistics	5	4	4	4	4	4
Density of population	5	3	3	3	3	3
Association with other values	5	4	4	3	3	4
Scenery	5	4	4	3	3	3
Uniqueness	5	4	3	4	4	4
Observation conditions	10	4	3	4	4	4
Didactic potential	20	4	4	2	2	2
Geological diversity	10	4	4	2	2	2
Total Score		385 High	370 High	315 High	285 Moderate	320 High

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008).

**Table 28** focuses on the tourism potential use (PTU) of the geosites, considering factors like vulnerability, accessibility, use limitations, safety, logistics, population density, association with other values, scenery, uniqueness, observation conditions, interpretative potential, economic level, and proximity to recreational areas. All geosites scored high, with GS.N1 scoring 375, GS.N2 360, GS.N3 355, GS.N4 325, and GS.N5 350. These scores indicate that all the geosites possess a high potential for tourism, as per Lima (2008)'s threshold of greater than 301 for high potential.

**Table 28.** Quantitative evaluation of geosites for tourism potential use (PTU)

Touristic criteria	Weight	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
Vulnerability	10	4	4	4	4	4
Accessibility	10	4	4	4	1	4
Use limitations	5	4	4	4	4	4
Safety	10	3	3	3	3	3
Logistics	5	4	4	4	4	4
Density of population	5	3	3	3	3	3
Association with other values	5	4	4	3	3	4
Scenery	15	4	4	3	3	3
Uniqueness	10	4	3	4	4	4
Observation conditions	5	4	3	4	4	4

Interpretative potential	10	4	4	4	4	3
Economic level	5	2	2	2	2	2
Proximity of recreational areas	5	4	4	4	3	4
Total Score		375 High	360 High	355 High	325 High	350 High

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008).

**Table 29** evaluates the degradation risk of the geosites using criteria such as deterioration of geological features, proximity to areas/activities that may cause degradation, legal protection, accessibility, and population density. GS.N1, GS.N2, and GS.N4 scored low with totals of 185, 170, and 180, respectively, indicating minimal risk. GS.N3 and GS.N5 scored moderate with 280 and 245, suggesting a higher but still manageable risk of degradation. Scores below 200 are considered low risk, while those between 201 and 300 are moderate, according to **Lima (2008)** and **Brilha (2016)**.

**Table 29.** Degradation risk evaluation of geosites

Criteria	Weight	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
Deterioration of geological features	35	1	1	2	1	1
Proximity to areas/activities with potential to cause degradation	20	1	1	4	1	4
Legal protection	20	2	2	2	4	2
Accessibility	15	4	3	4	1	4
Density of population	10	3	3	3	3	3
Total Score		185 Low	170 Low	280 Moderate	180 Low	245 Moderate

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008; Brilha, 2016)

The use of the G-P method reveals that all areas possess a substantial scientific value, with two scoring particularly high (>301). When evaluating their educational potential, it appears that all sites score highly, except for the geosite of Piria, which achieves a moderate score (201-300). In terms of potential tourist use (PTU), all geosites score highly, demonstrating their strong geotourism potential. Lastly, an assessment of the risk of degradation shows that all geosites have low scores in this area, with the exception of Emporios (GS.N3) and Panagia Thermiani (GS.N5), which have a moderate score (201-300).

### 7.2.2. The M-GAM Method

The application of the M-GAM quantitative evaluation method, as demonstrated in **Tables 30 and 31**, presents a similar outcome.

More specifically, the application of the M-GAM method to the geosites in Nisyros, as shown in **Table 30**, provides a comprehensive evaluation across various criteria, highlighting the strengths and weaknesses of each geosite. The scientific and educational values (VSE) show

significant variability, with high scores for rarity and representativeness across most sites, particularly GS.N1 and GS.N2. These two sites also excel in scenic/aesthetic values (VSA), especially in terms of viewpoints and surrounding landscapes. However, the level of interpretation is consistently lower across all geosites.

In terms of protection (VPr), all geosites score well on current condition and vulnerability, reflecting good conservation practices. Functional values (VFn) show that accessibility is generally high, except for GS.N4, which is significantly less accessible. Additional natural and anthropogenic values are moderate, with the vicinity of emissive centers and important road networks being relatively low for most sites.

Touristic values (VTr) highlight some discrepancies, with GS.N1 and GS.N2 performing well in promotion, organized visits, and tourism infrastructure. However, the interpretative panels and the number of visitors is notably low across all sites, indicating a potential area for improvement. The restaurant service scores are high, suggesting good facilities for tourists, whereas tour guide services are minimal. Overall, the evaluation shows that while there are strengths in scientific and aesthetic values, there is room for enhancement in interpretation and visitor engagement.

**Table 30.** Calculation by M-GAM method of geosites in Nisyros (Tomić & Božić, 2014; Božić & Tomić, 2015)

	Values given by experts					Im	Total value (with Im factor)				
	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5		GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
<b>Main Values (MV)</b>											
Scientific/Educational value (VSE)											
1.Rarity	0.75	0.75	0.5	0.5	0.25	0.89	0.6675	0.6675	0.445	0.445	0.2225
2.Representativeness	0.75	0.75	0.5	0.5	0.25	0.79	0.5925	0.5925	0.395	0.395	0.1975
3.Knowledge of scientific issues	1	1	0.5	0.5	0.5	0.45	0.45	0.45	0.225	0.225	0.225
4.Level of interpretation	0.5	0.5	0.25	0.25	0.25	0.85	0.425	0.425	0.2125	0.2125	0.2125
Scenic/Aesthetic (VSA)											
5. Viewpoints	0.75	0.75	0.5	0.25	0.5	0.79	0.5925	0.5925	0.395	0.1975	0.395
6. Surface	1	1	0.5	0.5	0.5	0.54	0.54	0.54	0.27	0.27	0.27
7. Surrounding landscape and nature	1	1	0.75	0.75	0.5	0.95	0.95	0.95	0.7125	0.7125	0.475
8. Environmental fitting of sites	1	1	0.5	0.5	0.5	0.68	0.68	0.68	0.34	0.34	0.34
<b>Protection (VPr)</b>											
9. Current condition	1	1	0.5	0.5	0.5	0.83	0.83	0.83	0.415	0.415	0.415
10. Protection level	0.75	0.75	0.25	0.25	0.25	0.76	0.57	0.57	0.19	0.19	0.19
11. Vulnerability	1	1	0.5	0.5	0.5	0.58	0.58	0.58	0.29	0.29	0.29

12. Suitable number of visitors	1	1	1	1	1	0.42	0.42	0.42	0.42	0.42	0.42
<b>Additional values (AV)</b>											
<b>Functional values (VF<sub>n</sub>)</b>											
13. Accessibility	1	1	1	0.25	1	0.75	0.75	0.75	0.75	0.1875	0.75
14. Additional natural values	0.75	0.75	0.75	0.5	0.5	0.71	0.5325	0.5325	0.5325	0.355	0.355
15. Additional anthropogenic values	0.75	0.75	0.5	0.25	0.5	0.7	0.525	0.525	0.35	0.175	0.35
16. Vicinity of emissive centers	0	0	0.25	0	0	0.48	0	0	0.12	0	0
17. Vicinity of important road network	0.25	0.25	0.25	0	0.25	0.62	0.155	0.155	0.155	0	0.155
18. Additional functional values	0.5	0.5	0.5	0	0.5	0.59	0.295	0.295	0.295	0	0.295
<b>Touristic values (VTr)</b>											
19. Promotion	0.5	0.5	0.25	0.25	0.25	0.85	0.425	0.425	0.2125	0.2125	0.2125
20. Organized visits	1	1	1	0	0.75	0.56	0.56	0.56	0.56	0	0.42
21. Vicinity of visitor's centers	0.5	0.5	0.5	0.5	0.5	0.87	0.435	0.435	0.435	0.435	0.435
22. Interpretative panels	0.25	0.25	0.25	0	0	0.81	0.2025	0.2025	0.2025	0	0
23. Number of visitors	0.75	0.25	0.25	0.25	0.25	0.43	0.3225	0.1075	0.1075	0.1075	0.1075
24. Tourism infrastructure	0.75	0.75	0.5	0	0.25	0.73	0.5475	0.5475	0.365	0	0.1825
25. Tour guide service	0.25	0.25	0	0	0	0.87	0.2175	0.2175	0	0	0
26. Hostelry service	0.5	0.5	0.5	0.5	0.5	0.73	0.365	0.365	0.365	0.365	0.365
27. Restaurant service	1	1	1	0.5	0.75	0.78	0.78	0.78	0.78	0.39	0.585

The results of the application of the M-GAM method in Nisyros, summarized in **Table 31**, reveal significant differences in the overall values and potential of the geosites.

Geosites GS.N1 and GS.N2 both achieved the highest total scores for the main values, with a combined score of 7.2975. This high score is attributed to their strong performance across scientific/educational value (VSE), scenic/aesthetic value (VSA), and protection (VPr). These geosites also performed well in the additional values, particularly in functional values (VF<sub>n</sub>) and touristic values (VTr), with GS.N1 scoring slightly higher due to its stronger touristic infrastructure. The high scores indicate that these sites are well-preserved, scientifically significant, and aesthetically pleasing, making them prime locations for both educational and tourist activities.

GS.N3 follows with a moderate total main value score of 4.31 and a relatively higher additional value score of 5.23. This indicates that while GS.N3 has moderate scientific and

aesthetic importance, it has considerable potential for tourism and functional use. The geosite's accessibility and touristic infrastructure contribute positively to its additional value score.

GS.N4 and GS.N5 scored the lowest in the evaluation. GS.N4 has a total main value score of 4.1125 and an additional value score of 2.2275, showing that it has significant limitations in both its main and additional values, particularly in terms of accessibility and infrastructure. Similarly, GS.N5, with a main value score of 3.6525 and an additional value score of 4.2125, shows that while it has moderate scientific and aesthetic values, its touristic and functional potential is relatively limited.

Overall, the application of the M-GAM method highlights that GS.N1 and GS.N2 are the most valuable geosites in Nisyros, offering high scientific, educational, and touristic potential. In contrast, GS.N4 and GS.N5 require significant improvements in both conservation and visitor facilities to enhance their value and accessibility.

**Table 31.** Results of the application of the M-GAM method in Nisyros.

Geosite	Main values		Additional values		Field area
	VSE+VSA+VPr	SUM	VFn+VTr	SUM	
GS.N1	2.135+2.7625+2.4	7.2975	2.2575+3.855	6.1125	Z22
GS.N2	2.135+2.7625+2.4	7.2975	2.2575+3.64	5.8975	Z22
GS.N3	1.2775+1.7175+1.315	4.31	2.2025+3.0275	5.23	Z22
GS.N4	1.2775+1.52+1.315	4.1125	0.7175+1.51	2.2275	Z21
GS.N5	0.8575+1.48+1.315	3.6525	1.905+2.3075	4.2125	Z11

The diagram below (**Diagram 5**) illustrates the conclusive outcomes of the method (**Table 22**). Concerning the results, field Z22 encompasses three out of the five examined areas. These three areas exhibit similar values and features regarding geological characteristics. In contrast, fields Z11 and Z21 each encompass one region that attains the lowest score when compared to the other three.

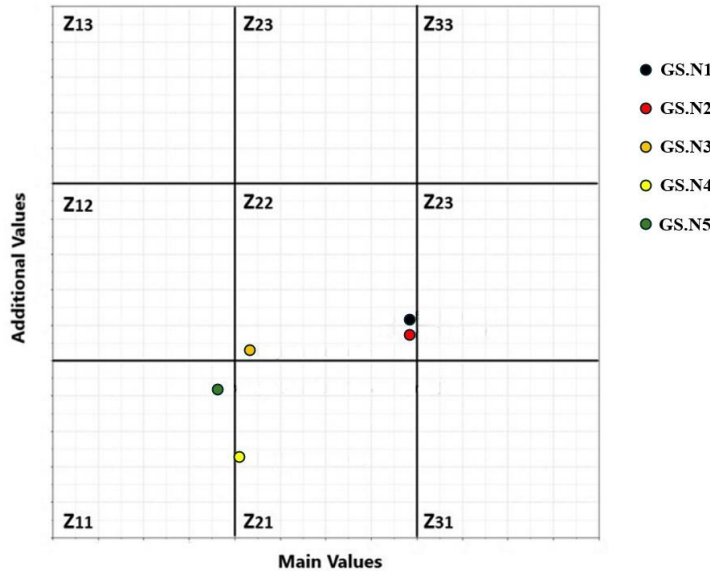


Diagram 5. The display of results from the M-GAM method.

### 7.2.3. GEOAM

The scoring system across various criteria for the geomorphosites of Nisyros reveals several insights. **Tables 32-40** present the results for all eight main sectors of the innovative GEOAM methodology, including the final scores and their characterizations.

For Site Management and Visitor Experience (SMVE), GS.N1 and GS.N2 score highly on average (4.33 and 4.16 respectively), indicating excellent accessibility, signage, visitor facilities, and safety. GS.N4 has the lowest score (2.83), suggesting room for improvement in visitor experience (**Table 32**).

Table 32. Scoring system in the geomorphosites of Nisyros on SMVE

SMVE—Site Management and Visitor Experience					
Subcriteria	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
Site accessibility	5	5	5	3	5
Signage and interpretation	5	4	3	2	3
Staff knowledge and visitor interaction	4	4	3	3	3
Visitor facilities	4	4	4	3	4
Site maintenance	4	4	4	3	4
Safety and security	4	4	3	3	3
Average	4.33	4.16	3.66	2.83	3.66

In terms of Natural Resource Management (NRM), GS.N1 and GS.N2 maintain a consistent average score of 3.60, showing strong performance in biodiversity conservation, ecosystem preservation, and pollution control. Conversely, GS.N3, GS.N4, and GS.N5 have lower scores (2.80), indicating areas for improvement, particularly in climate change adaptation (**Table 33**).

**Table 33.** Scoring system in the geomorphosites of Nisyros on NRM

<b>NRM—Natural Resource Management</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Conservation of biodiversity	3	3	3	3	3
Preservation of ecosystems	4	4	3	3	3
Sustainable use of natural resources	4	4	3	3	3
Pollution prevention and control	4	4	3	3	3
Climate change mitigation and adaptation	3	3	2	2	2
Average	3.60	3.60	2.80	2.80	2.80

Environmental Education and Interpretation (EEI) scores are relatively low across all sites, with GS.N1 and GS.N2 at the higher end (2.00) and GS.N3, GS.N4, and GS.N5 slightly lower (1.60). This suggests a need for better interpretive signage, trained staff, and integration of interactive educational activities (**Table 34**).

**Table 34.** Scoring system in the geomorphosites of Nisyros on EEI

<b>EEI—Environmental Education and Interpretation</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Presence of interpretive signage or exhibits	1	1	1	1	1
Availability of trained interpretive staff or volunteers	3	3	2	2	2
Integration of environmental education and interpretation	3	3	2	2	2
Inclusion of interactive and hands-on activities	2	2	2	2	2
Incorporation of environmentally friendly practices	1	1	1	1	1
Average	2.00	2.00	1.60	1.60	1.60

For Cultural and Historical Significance (CHS), GS.N1 scores the highest (4.00) due to its strong historical and cultural significance, while GS.N4 scores the lowest (2.00), indicating less emphasis on cultural and historical education (**Table 35**).

**Table 35.** Scoring system in the geomorphosites of Nisyros on CHS

<b>CHS—Cultural and Historical Significance</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Historical significance	5	5	3	2	5
Cultural significance	4	4	3	2	4
Interpretation and education	4	3	3	2	3
Cultural diversity and inclusivity	3	3	2	2	2
Average	4.00	3.75	2.75	2.00	3.50

Regarding Community Involvement and Engagement (CIE), GS.N1 and GS.N2 score exceptionally high (4.75), demonstrating robust stakeholder participation, community benefits, and outreach efforts. GS.N4, with a score of 3.00, shows the least community involvement (**Table 36**).

**Table 36.** Scoring system in the geomorphosites of Nisyros on CIE

<b>CIE—Community Involvement and Engagement</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Stakeholder participation	5	5	3	2	3
Cultural sensitivity	4	4	3	2	4
Community benefits	5	5	5	5	5
Outreach and communication	5	5	5	3	4
Average	4.75	4.75	4.00	3.00	4.00

1

Geoethics (GE) scores are high for GS.N1 and GS.N2 (4.20), reflecting strong environmental impact management and social responsibility. GS.N4 scores the lowest (2.80), indicating a need for improved transparency and professional conduct (**Table 37**).

**Table 37.** Scoring system in the geomorphosites of Nisyros on GE

<b>GE—Geoethics</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Environmental impact	5	5	3	3	3
Cultural heritage	4	4	3	3	3
Social responsibility	4	4	3	3	4
Transparency and accountability	4	4	3	2	3
Professional conduct	4	4	3	3	3
Average	4.20	4.20	3.00	2.80	3.00

In Economic Viability (EV), GS.N1 and GS.N2 score very high (4.60), showing strong potential for tourist revenue and local economic impact. GS.N4 scores the lowest (2.80), suggesting weaker economic viability (**Table 38**).

**Table 38.** Scoring system in the geomorphosites of Nisyros on EV

<b>EV—Economic Viability</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>
Tourist revenue potential	5	5	3	3	4
Local economic impact	5	5	4	3	4
Sustainability of economic benefits	4	4	3	3	3
Cost-effectiveness of management	4	4	3	2	3
Innovative economic models	5	5	4	3	4
Average	4.60	4.60	3.40	2.80	3.60

Sustainable Development (SD) scores reveal GS.N1 and GS.N2 as the highest (3.33), indicating good resource efficiency and social-economic impacts. All sites have low scores in climate change adaptation (1.00), highlighting a significant area for improvement (**Table 39**).

**Table 39.** Scoring system in the geomorphosites of Nisyros on SD

<b>SD—Sustainable Development</b>					
<b>Subcriteria</b>	<b>GS.N1</b>	<b>GS.N2</b>	<b>GS.N3</b>	<b>GS.N4</b>	<b>GS.N5</b>

Resource efficiency	4	4	4	4	4
Waste management	3	3	3	2	3
Biodiversity conservation	3	3	3	3	3
Social and economic impacts	5	5	4	3	4
Climate change adaptation	1	1	1	1	1
Cultural heritage preservation	4	4	3	3	3
Average	3.33	3.33	3.00	2.66	3.00

**Table 40** details the scoring system used to evaluate the geosites of Nisyros based on the GEOAM methodology. This table integrates weighted criteria (each criterion is assigned a specific weight, reflecting its importance in the overall evaluation) to determine the overall performance and implementation level of each geosite. GS.N1 and GS.N2 emerge as the most well-managed and impactful geosites on Nisyros, showing high levels of visitor experience, resource management, and community engagement. In contrast, GS.N3, GS.N4, and GS.N5 require targeted improvements, particularly in environmental education, economic viability, and sustainable development practices to enhance their overall implementation and impact. Based on this, GS.N1 and GS.N2 are highlighted as leading sites with high implementation levels, while GS.N3, GS.N4, and GS.N5 demonstrate moderate performance with specific areas needing attention. This evaluation helps in identifying focus areas for enhancing the management, educational value, and overall sustainability of these geosites.

**Table 40.** Scoring system for the geosites of Nisyros and the final scores according GEOAM.

Criteria	Weight	GS.N1	GS.N2	GS.N3	GS.N4	GS.N5
SMVE	10%	4.33	4.16	3.66	2.83	3.66
NRM	10%	3.60	3.60	2.80	2.80	2.80
EEI	30%	2.00	2.00	1.60	1.60	1.60
CHS	10%	4.00	3.75	2.75	2.00	3.50
GE	20%	4.78	4.75	4.00	3.00	4.00
EV	5%	4.20	4.20	3.00	2.80	3.00
CIE	5%	4.60	4.60	3.40	2.80	3.60
SD	10%	3.33	3.33	3.00	2.66	3.00
Final Score		3.522	3.474	2.821	2.389	2.906
Characterization of score		HI	HI	MI	MI	MI

1<Low Implementation<2; 2≤Medium Implementation<3; 3≤High Implementation<4; 4≤Very High Implementation<4.5 From 4.5 up: Extremely High Implementation

## 7.3. Samos island

### 7.3.1. The General-Purpose Model—G-P Method

The application of G-P method provides a comprehensive evaluation of the geosites in Samos island, in terms of scientific value, educational potential, tourism potential, and degradation risk.

**Table 41** evaluates geosites based on their scientific value using criteria such as representativeness, key locality, scientific knowledge, integrity, geological diversity, rarity, and use limitations. Each criterion has an assigned weight reflecting its importance. The results show that GS.S1 scores significantly higher with a total score of 330, categorizing it as having high scientific value. In contrast, GS.S2, GS.S3, and GS.S4 score lower (180, 165, and 165 respectively), placing them in the low scientific value category. This suggests that GS.S1 is of considerable scientific importance, while the other sites are less significant scientifically according to the evaluated criteria.

**Table 41.** Quantitative evaluation of geosites for scientific value (SV) according to Brilhas' method

Scientific Criteria	Weight	GS.S1	GS.S2	GS.S3	GS.S4
Representativeness	30	4	2	2	2
Key locality	20	4	1	1	1
Scientific knowledge	5	4	2	2	2
Integrity	15	2	2	2	2
Geological diversity	5	2	2	2	2
Rarity	15	4	2	2	1
Use limitations	10	1	2	2	2
Total Score		330	180	180	165
		High	Low	Low	Low

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)

**Table 42** assesses the educational potential of geosites using criteria such as vulnerability, accessibility, use limitations, safety, logistics, population density, association with other values, scenery, uniqueness, observation conditions, didactic potential, and geological diversity. Each criterion has a different weight reflecting its importance. GS.S1 scores 325, categorized as high educational potential, while GS.S2 and GS.S3 both score 290, categorizing them as having moderate educational potential. GS.S4 scores 310, placing it in the high educational potential category. These scores indicate that GS.S1 and GS.S4 are particularly well-suited for educational use, while GS.S2 and GS.S3 are moderately suitable.

**Table 42.** Quantitative evaluation of geosites for educational potential use (PEU) according to Brilhas' method

Educational criteria	Weight	GS.S1	GS.S2	GS.S3	GS.S4
Vulnerability	10	3	3	3	3
Accessibility	10	4	2	2	4
Use limitations	5	3	4	4	4
Safety	10	4	4	4	4
Logistics	5	4	4	4	4
Density of population	5	4	4	4	4
Association with other values	5	4	4	4	4
Scenery	5	4	2	2	2
Uniqueness	5	4	2	2	2
Observation conditions	10	4	4	4	4
Didactic potential	20	2	2	2	2
Geological diversity	10	2	2	2	2
Total Score		325	290	290	310
		High	Moderate	Moderate	High

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)

**Table 43** evaluates the tourism potential of geosites based on criteria such as vulnerability, accessibility, use limitations, safety, logistics, population density, association with other values, scenery, uniqueness, observation conditions, interpretative potential, economic level, and proximity to recreational areas. The weights of these criteria reflect their importance in tourism. GS.S1 scores 370, categorized as having high tourism potential, while GS.S2 and GS.S3 both score 305, also categorized as having high tourism potential. GS.S4 scores 320, again placing it in the high tourism potential category. These results indicate that all the geosites exhibit high tourism potential, suggesting they are all well-suited to attract and accommodate tourists.

**Table 43.** Quantitative evaluation of geosites for tourism potential use (PTU)

Touristic criteria	Weight	GS.S1	GS.S2	GS.S3	GS.S4
Vulnerability	10	3	3	3	4
Accessibility	10	4	2	2	1
Use limitations	5	3	4	4	4
Safety	10	4	4	4	3
Logistics	5	4	4	4	4
Density of population	5	4	4	4	3
Association with other values	5	4	4	4	3
Scenery	15	4	2	2	3
Uniqueness	10	4	2	2	4
Observation conditions	5	4	4	4	4
Interpretative potential	10	4	4	4	4
Economic level	5	1	1	1	2
Proximity of recreational areas	5	4	4	4	3
Total Score		370 High	305 High	305 High	320 High

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008)

**Table 44** assesses the risk of degradation for geosites using criteria such as the deterioration of geological features, proximity to areas/activities with potential to cause degradation, legal protection, accessibility, and population density. Each criterion has a specific weight reflecting its importance in determining degradation risk. GS.S1 scores 195, categorizing it as having a low degradation risk. In contrast, GS.S2, GS.S3, and GS.S4 score higher (205, 205, and 215 respectively), categorizing them as having moderate degradation risk. These scores indicate that GS.S1 is at a lower risk of degradation, while GS.S2, GS.S3, and GS.S4 require more attention to protect these sites from potential degradation.

**Table 44.** Degradation risk evaluation of geosites

Criteria	Weight	GS.S1	GS.S2	GS.S2	GS.S4
Deterioration of geological features	35	1	1	1	1
Proximity to areas/activities with potential to cause degradation	20	2	3	3	2
Legal protection	20	1	2	2	2
Accessibility	15	4	2	2	4
Density of population	10	4	4	4	4
Total Score		195 Low	205 Moderate	205 Moderate	215 Moderate

≤200 Low, 201–300 Moderate, >301 High (Lima, 2008; Brilha, 2016)

The application of the G-P method indicates that GS.S1 consistently scores high in scientific, educational, and tourism potential while maintaining a low degradation risk, making it an exemplary site. GS.S2, GS.S3, and GS.S4, while showing moderate to high potential in various aspects, require targeted measures to mitigate moderate degradation risks and enhance their educational and scientific value.

### 7.3.2. The M-GAM Method

**Table 45** presents a detailed assessment of geosites in Samos using the Modified Geosite Assessment Model (M-GAM) method. This evaluation incorporates both main and additional values, each further divided into specific criteria, and assigns weighted scores to four geosites (GS.S1, GS.S2, GS.S3, GS.S4).

The Main Values (MV) section is broken down into three categories: Scientific/Educational Value (VSE), Scenic/Aesthetic Value (VSA), and Protection Value (VPr). In the VSE category, criteria such as rarity, representativeness, scientific knowledge, and level of interpretation are considered. For instance, GS.S1 scores highly on knowledge of scientific issues (1) and rarity (0.75), which are then adjusted by importance factors (Im), resulting in values such as 0.6675 for rarity and 0.45 for scientific knowledge. In the VSA category, criteria like viewpoints, surface, surrounding landscape, and environmental fitting are included. GS.S1 scores highly in surrounding landscape (1) and environmental fitting (1), adjusted to final values of 0.95 and 0.68, respectively. The VPr category evaluates current condition, protection level, vulnerability, and suitable number of visitors, with GS.S1 scoring high in protection level (1) and current condition (0.75), adjusted to values of 0.76 and 0.6225, respectively.

The Additional Values (AV) section includes Functional Values (VF<sub>n</sub>) and Touristic Values (VTr). Functional values encompass accessibility, additional natural and anthropogenic values, and vicinity to emissive centers and road networks. GS.S1 scores 0.25 in accessibility, adjusted to 0.1875. Touristic values consider promotion, organized visits, proximity to visitor centers, interpretative panels, and tourism infrastructure. GS.S1 scores highly in promotion and organized visits, resulting in high adjusted values such as 0.85 for promotion.

Overall, GS.S1 stands out with the highest scores across most criteria, indicating its significant scientific, educational, scenic, and protection values, as well as strong functional and touristic potential.

**Table 45.** Calculation by M-GAM method of geosites in Samos (Tomić & Božić, 2014; Božić & Tomić, 2015)

	Values given by experts				Im	Total value (with Im factor)			
	GS.S1	GS.S2	GS.S3	GS.S4		GS.S1	GS.S2	GS.S3	GS.S4
<b>Main Values (MV)</b>									
Scientific/Educational value (VSE)									

1.Rarity	0.75	0.25	0.25	0.25	0.89	0.6675	0.2225	0.2225	0.2225
2.Representativeness	0.75	0.25	0.25	0.25	0.79	0.5925	0.1975	0.1975	0.1975
3.Knowledge of scientific issues	1	0.75	0.75	0.75	0.45	0.45	0.3375	0.3375	0.3375
4.Level of interpretation	0.5	0.75	0.75	0.75	0.85	0.425	0.6375	0.6375	0.6375
Scenic/Aesthetic (VSA)									
5. Viewpoints	0.5	0.5	0.5	0.75	0.79	0.395	0.395	0.395	0.5925
6. Surface	1	0.5	0.5	0.5	0.54	0.54	0.27	0.27	0.27
7. Surrounding landscape and nature	1	0.5	0.5	0.5	0.95	0.95	0.475	0.475	0.475
8. Environmental fitting of sites	1	1	1	1	0.68	0.68	0.68	0.68	0.68
<b>Protection (VPr)</b>									
9. Current condition	0.75	0.5	0.5	0.75	0.83	0.6225	0.415	0.415	0.6225
10. Protection level	1	0.25	0.25	0.25	0.76	0.76	0.19	0.19	0.19
11. Vulnerability	0.5	0.5	0.5	0.5	0.58	0.29	0.29	0.29	0.29
12. Suitable number of visitors	0.25	1	1	1	0.42	0.105	0.42	0.42	0.42
<b>Additional values (AV)</b>									
<b>Functional values (VFn)</b>									
13. Accessibility	0.25	0.5	0.5	1	0.75	0.1875	0.375	0.375	0.75
14. Additional natural values	0.75	0.75	0.75	0.75	0.71	0.5325	0.5325	0.5325	0.5325
15. Additional anthropogenic values	0.75	0.75	0.75	0.75	0.7	0.525	0.525	0.525	0.525
16. Vicinity of emissive centers	0.5	0.5	0.5	0.5	0.48	0.24	0.24	0.24	0.24
17. Vicinity of important road network	0.5	0.5	0.5	0.5	0.62	0.31	0.31	0.31	0.31
18. Additional functional values	0.5	0.5	0.5	0.5	0.59	0.295	0.295	0.295	0.295
<b>Touristic values (VTr)</b>									
19. Promotion	1	0.5	0.5	0.5	0.85	0.85	0.425	0.425	0.425
20. Organized visits	1	0.25	0.25	0.5	0.56	0.56	0.14	0.14	0.28
21. Vicinity of visitor's centers	1	0.75	0.75	1	0.87	0.87	0.6525	0.6525	0.87
22. Interpretative panels	1	0.25	0.25	0.5	0.81	0.81	0.2025	0.2025	0.405
23. Number of visitors	0.75	0.25	0.25	0.75	0.43	0.3225	0.1075	0.1075	0.3225
24. Tourism infrastructure	1	0.25	0.25	0.5	0.73	0.73	0.1825	0.1825	0.365
25. Tour guide service	1	0.25	0.25	0.5	0.87	0.87	0.2175	0.2175	0.435
26. Hostelry service	1	1	1	1	0.73	0.73	0.73	0.73	0.73
27. Restaurant service	0.75	0.5	0.5	0.75	0.78	0.585	0.39	0.39	0.585

**Table 46** summarizes the results of applying the M-GAM method to the geosites in Samos, combining both main values (MV) and additional values (AV).

GS.S1 emerges as the most valuable geosite with a total MV score of 6.4775 and an AV score of 8.4175, making it the most significant in terms of combined scientific, educational, scenic, protection, functional, and touristic values. This indicates that GS.S1 is a well-rounded geosite with high potential for various uses.

GS.S2 and GS.S3 both have identical MV scores of 4.53 and AV scores of 5.325, indicating moderate value in both main and additional aspects. These geosites are valuable but not as highly rated as GS.S1.

GS.S4 has a slightly higher MV score of 4.935 and an AV score of 7.07 compared to GS.S2 and GS.S3, suggesting it has slightly higher scenic and functional values, enhancing its overall attractiveness.

**Table 46.** Results of the application of the M-GAM method in Samos

Geosite	Main values		Additional values		Field area
	VSE+VSA+VPr	SUM	VF <sub>n</sub> +VTr	SUM	
GS.S1	2.135+2.565+1.7775	6.4775	2.09+6.3275	8.4175	Z22
GS.S2	1.395+1.82+1.315	4.53	2.2775+3.0475	5.325	Z22
GS.S3	1.395+1.82+1.315	4.53	2.2775+3.0475	5.325	Z22
GS.S4	1.395+2.0175+1.5225	4.935	2.6525+4.4175	7.07	Z22

The **Diagram 6** displays the conclusive outcomes of the M-GAM method. Regarding the outcomes, field Z22 includes all the areas examined. These four areas (GS.S1, GS.S2, GS.S3, GS.S4) demonstrate comparable values and characteristics in terms of geological characteristics. This indicates a general homogeneity in geological features across the geosites in Samos, with variations primarily in specific criteria such as rarity, representativeness, and protection levels. The diagram visually reinforces the quantitative data presented in **Tables 70** and **71**, highlighting GS.S1's exceptional values and the overall similarity among the other geosites.

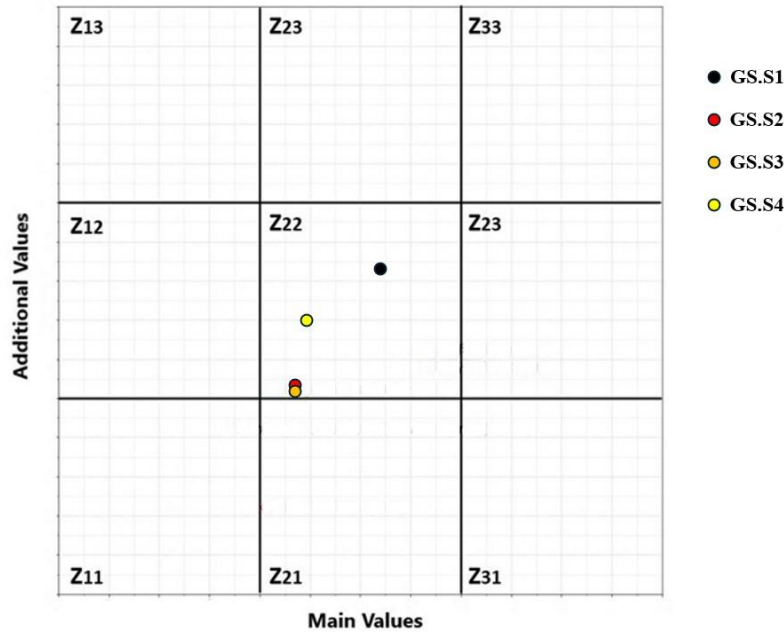


Diagram 6. The display of results from the M-GAM method

### 7.3.3. GEOAM

The implementation of GEOAM in Samos island provides a comprehensive evaluation of its geosites. Table 47 assesses the geosites of Samos based on various subcriteria related to site management and visitor experience. GS.S1 consistently scores the highest, particularly in site accessibility, visitor facilities, site maintenance, and safety and security, resulting in an average score of 4.33. GS.S4 follows with strong scores in similar subcriteria, achieving an average of 3.83. GS.S2 and GS.S3, however, both score significantly lower across all subcriteria, with averages of 2.00, indicating room for improvement in site management and visitor experience aspects.

Table 47. Scoring system in the geomorphosites of Samos on SMVE

SMVE—Site Management and Visitor Experience				
Subcriteria	GS.S1	GS.S2	GS.S3	GS.S4
Site accessibility	5	4	4	5
Signage and interpretation	4	3	3	4
Staff knowledge and visitor interaction	2	1	1	1
Visitor facilities	5	2	2	5
Site maintenance	5	1	1	5
Safety and security	5	1	1	3
Average	4.33	2.00	2.00	3.83

Table 48 evaluates the geosites based on their natural resource management. GS.S1 and GS.S4 lead with an average score of 3.40, demonstrating strong performance in conserving biodiversity, preserving ecosystems, and pollution prevention. Both GS.S2 and GS.S3 receive

slightly lower average scores of 3.00, indicating they are fairly effective but could enhance their efforts in areas such as climate change mitigation.

**Table 48.** Scoring system in the geomorphosites of Samos on NRM

<b>NRM—Natural Resource Management</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Conservation of biodiversity	4	4	4	4
Preservation of ecosystems	4	3	3	4
Sustainable use of natural resources	3	3	3	3
Pollution prevention and control	4	4	4	4
Climate change mitigation and adaptation	2	1	1	2
Average	3.40	3.00	3.00	3.40

**Table 49** focuses on environmental education and interpretation. GS.S1 scores moderately with an average of 2.20, driven by higher scores in the availability of interpretive staff and the presence of interpretive signage. GS.S2, GS.S3, and GS.S4 each score an average of 1.00, reflecting a need for substantial improvement in all subcriteria, particularly in interactive activities and environmentally friendly practices.

**Table 49.** Scoring system in the geomorphosites of Samos on EEI

<b>EEI—Environmental Education and Interpretation</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Presence of interpretive signage or exhibits	2	1	1	1
Availability of trained interpretive staff or volunteers	3	1	1	1
Integration of environmental education and interpretation	2	1	1	1
Inclusion of interactive and hands-on activities	2	1	1	1
Incorporation of environmentally friendly practices	2	1	1	1
Average	2.20	1.00	1.00	1.00

**Table 50** highlights the cultural and historical significance of the geosites. All sites score uniformly high in historical and cultural significance. However, GS.S1 stands out with a higher average score of 4.00 due to its stronger interpretation and educational efforts. The other sites, GS.S2, GS.S3, and GS.S4, each have an average score of 3.00, indicating less emphasis on interpretation and inclusivity.

**Table 50.** Scoring system in the geomorphosites of Samos on CHS

<b>CHS—Cultural and Historical Significance</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Historical significance	5	5	5	5
Cultural significance	5	5	5	5
Interpretation and education	4	1	1	1
Cultural diversity and inclusivity	2	1	1	1
Average	4.00	3.00	3.00	3.00

**Table 51** assesses the geosites based on geoethical considerations. GS.S1 scores the highest with an average of 4.80, excelling in all subcriteria including environmental impact, cultural heritage, and social responsibility. GS.S4 follows with an average of 3.80. GS.S2 and GS.S3, with lower scores of 2.00, reveal weaknesses in areas like transparency, accountability, and professional conduct.

**Table 51.** Scoring system in the geomorphosites of Samos on GE

<b>GE—Geoethics</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Environmental impact	4	3	3	4
Cultural heritage	5	3	3	5
Social responsibility	5	2	2	4
Transparency and accountability	5	1	1	3
Professional conduct	5	1	1	3
Average	4.80	2.00	2.00	3.80

**Table 52** evaluates economic viability, where GS.S1 excels with an average score of 4.80, indicating high potential for tourist revenue and local economic impact. GS.S4 also performs well with an average of 4.00. Both GS.S2 and GS.S3, scoring 3.20, show moderate economic viability but have room for improvement in sustaining economic benefits and innovating economic models.

**Table 52.** Scoring system in the geomorphosites of Samos on EV

<b>EV—Economic Viability</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Tourist revenue potential	5	3	3	5
Local economic impact	5	4	4	5
Sustainability of economic benefits	4	2	2	3
Cost-effectiveness of management	5	4	4	4
Innovative economic models	5	3	3	3
Average	4.80	3.20	3.20	4.00

**Table 53** examines community involvement and engagement. GS.S1 and GS.S4 score the highest with averages of 4.00, demonstrating effective stakeholder participation, cultural sensitivity, and community benefits. GS.S2 and GS.S3 have low average scores of 1.25, indicating a need for better community engagement and outreach efforts.

**Table 53.** Scoring system in the geomorphosites of Samos on CIE

<b>CIE—Community Involvement and Engagement</b>				
<b>Subcriteria</b>	<b>GS.S1</b>	<b>GS.S2</b>	<b>GS.S3</b>	<b>GS.S4</b>
Stakeholder participation	3	1	1	3
Cultural sensitivity	5	2	2	5
Community benefits	5	1	1	5
Outreach and communication	3	1	1	3
Average	4.00	1.25	1.25	4.00

**Table 54** assesses sustainable development. GS.S1 and GS.S4 again lead with high averages of 4.00 and 3.83, respectively, excelling in resource efficiency, waste management, and biodiversity conservation. GS.S2 and GS.S3, both scoring 2.83, highlight areas for improvement, particularly in climate change adaptation and cultural heritage preservation.

**Table 54.** Scoring system in the geomorphosites of Samos on SD

SD—Sustainable Development				
Subcriteria	GS.S1	GS.S2	GS.S3	GS.S4
Resource efficiency	4	4	4	4
Waste management	5	1	1	5
Biodiversity conservation	4	4	4	4
Social and economic impacts	5	4	4	5
Climate change adaptation	1	1	1	1
Cultural heritage preservation	5	3	3	4
Average	4.00	2.83	2.83	3.83

**Table 55** provides the final scores for each geosite, derived from the weighted average of the scores across all criteria. GS.S1 achieves the highest final score of 3.63, classified as High Implementation (HI), indicating excellent overall performance. GS.S4 follows with a score of 2.86, classified as Medium Implementation (MI), showing good performance but with areas needing improvement. GS.S2 and GS.S3 both score 2.00, also classified as Medium Implementation (MI), highlighting the need for targeted interventions to elevate their performance. More specifically, The Tunnel of Eupalinos (GS.S1) leads with a strong score of 3.63, indicating "High Implementation" across various criteria. It excels in management, visitor experience, and sustainability. Opportunities for improvement lie in environmental education. The Ancient Quarries of Agiades present moderate to promising performance. GS.S2 scores 2.00, showing potential with balanced management. GS.S3 scores 2.86, excelling in accessibility and conservation, but needs improvement in education and sustainability.

GS.S4 demonstrates moderate to high implementation, scoring 2.86, emphasizing accessibility and safety. It shows promise in education and sustainability but needs enhancement.

Panagia Spiliani cave requires strategies for education, responsible tourism, and community engagement to preserve its sanctity and ecological balance.

**Table 55.** Scoring system for the geosites of Samos and the final scores according GEOAM.

Criteria	Weight	GS.S1	GS.S2	GS.S3	GS.S4
SMVE	10%	4.33	2	2	3.83
NRM	10%	3.4	3	3	3.4
EEI	30%	2.2	1	1	1
CHS	10%	4	3	3	3
GE	20%	4.8	2	2	3.8
EV	5%	4.8	3.2	3.2	4
CIE	5%	4	1.25	1.25	4
SD	10%	4	2.83	2.83	3.83
Final Score		3.63	2.00	2.00	2.86

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Characterization of score	HI	MI	MI	MI
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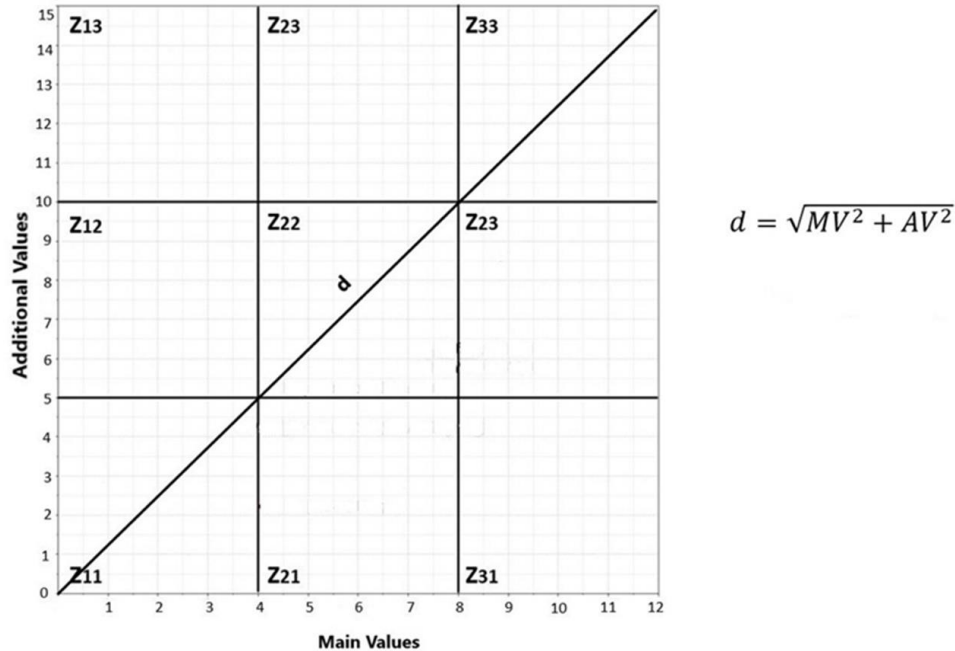
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## 7.4 Comparative analysis between the 3 methods

Describing the geological narrative of a protected area is akin to narrating a segment of Earth's history, as articulated by **Tormey (2019)**. In this context, a location characterized by significant geological and geomorphological attributes and ongoing processes should possess educational significance, contributing to an enhanced understanding of the dynamic phenomena constantly unfolding on the Earth's surface. The educational worth of a particular geoheritage site also plays a role in the conservation of natural resources, aligning with a fundamental principle of Geotourism. Typically, the assessment of educational value revolves around evaluating the site's representativeness of features or processes, its exemplariness, and its potential for educational purposes.

The primary aim of this study was to evaluate the geological educational potential of geosites within Kalymnos, Nisyros and Samos. This evaluation was carried out using three distinct methods, each with its own approach, with the intention of comparing their outcomes and identifying potential limitations in both approaches. The first method selected was the general-purpose model (G-P method), primarily due to its comprehensive examination of various aspects graded and assessed for their geological educational potential. In contrast, the M-GAM method incorporates the perspectives of visitors, who, as non-experts, offer a unique viewpoint seldom considered or quantified in traditional geosite assessment methods. Lastly, the innovative method GEOM is applied, the subcriteria of which focus on the geoeducational spectrum of the implementation regarding the geosites.

To facilitate a more accurate and objective comparison between the two methods of assessing the educational potential of the study areas, the results were converted into a percentage scale (%). More specifically, to enable a more equitable and objective comparison of the two assessment methods regarding the educational potential of the study areas, the results were normalized to a percentage scale (%). This process led to some differences in the results obtained from the two evaluation methods. Specifically, this normalization was exclusively applied to the educational value, given that our research focuses on evaluating the geoeducational potential of geological heritage. To illustrate, the G-P method has a maximum attainable value of 400, so all scores were scaled down to a range with a maximum value of 100. Similarly, the GEOAM method has a maximum value of 5, therefore, all scores were adjusted to a scale where the highest possible value was 100. The M-GAM method, which can yield a maximum impact value in the Z33 region, underwent a parallel adjustment. When the horizontal axis (Main Values) is marked with a value of 12 and the vertical axis (Additional Values) with a value of 15, it represents the utmost possible distance from the origin of the axes. The subsequent formula is used to compute the distance of a point from the origin in the plane: (**Diagram 7**).



**Diagram 7.** Maximum potential distance from the origin 0 (0,0).

In our study, the maximum potential values are  $MV = 12$  and  $AV = 15$ , resulting in a maximum distance of:

$$d_{max} = \sqrt{12^2 + 15^2} \cong 19.2.$$

Ultimately, the outcomes are transformed into percentages, enabling straightforward comparisons on a unified scale.

**Table 56** provides the ultimate outcomes of the evaluation methods applied to the geosites across Kalymnos, Nisyros, and Samos. The table employs a grading scale to assess the geoevaluational worth of each specific geosite examined. The final scores resulting from the application of both the G-P (Geoevaluational Potential) Method and the M-GAM (Multi-Criteria Geosite Assessment Method) are documented, followed by the conversion of these results to a common scale for comparison.

For each island and its corresponding geosites, the table presents the final score of educational use achieved through both methods. The G-P Method and M-GAM Method scores are recorded separately, allowing for a comprehensive comparison of the outcomes. Additionally, the GEOAM final score for educational use is provided, serving as a reference point for the evaluation process.

The conversion of these scores to a percentage for the G-P Method, M-GAM Method, and GEOAM is documented, facilitating a standardized comparison across the different evaluation methods. This conversion enables stakeholders to gauge the relative performance of each geosite in terms of its educational value, regardless of the evaluation method employed.

Overall, **Table 56** offers a comprehensive overview of the educational value of geosites across the three islands, allowing for informed decision-making and the prioritization of resources for further development and enhancement of geoeducational initiatives.

**Table 56.** Results after the application of the two methods and after reduction to a common scale

Island	Geosites	G-P Method-Final score of education use	M-GAM method-Final score of education use		GEOAM Final score of education use	Conversion to a percentage for P-M method	Conversion to a percentage for M-GAM method	Conversion to a percentage for GEOAM method
			Main Value	Additional Value				
Kalymnos	GS.K1	320	5.4925	6.04	1.60	80.00	42.50	32.00
	GS.K2	340	5.4925	6.04	2.20	85.00	42.50	44.00
	GS.K3	270	2.2825	4.415	1.20	67.50	28.88	24.00
	GS.K4	320	4.81	5.7075	2.20	80.00	38.85	44.00
	GS.K5	295	4.31	5.08	1.60	73.75	34.68	32.00
	GS.K6	310	4.3	5.085	1.60	77.50	34.63	32.00
	GS.K7	360	6.6625	7.64	2.00	90.00	52.76	40.00
	GS.K8	360	6.5575	7.265	2.00	90.00	50.93	40.00
Nisyros	GS.N1	385	7.2975	6.1125	2.00	96.25	49.53	40.00
	GS.N2	370	7.2975	5.8975	2.00	92.50	48.85	40.00
	GS.N3	315	4.31	5.23	1.60	78.75	35.26	32.00
	GS.N4	285	4.1125	2.2275	1.60	71.25	24.32	32.00
	GS.N5	320	3.6525	4.2125	1.60	80.00	29.01	32.00
Samos	GS.S1	325	6.4775	8.4175	2.20	81.25	55.20	44.00
	GS.S2	290	4.53	5.325	1.00	72.50	36.40	20.00
	GS.S3	290	4.53	5.325	1.00	72.50	36.40	20.00
	GS.S4	310	4.935	7.07	1.00	77.50	44.89	20.00

**Table 56** illustrates significant discrepancies in scores among the three methodologies concerning the educational value and utilization of geosites. It's important to emphasize that while M-GAM doesn't explicitly include criteria solely focused on the educational aspect of geosites, it integrates them with considerations of scientific value, naturally resulting in diverse conclusions. Similarly, G-P method assesses the potential educational dimension of a geotope in isolation, yet its criteria are not exclusively tailored to educational processes or broader educational dimensions. In contrast, GEOAM introduces a novel approach by incorporating five sub-criteria exclusively related to educational dimensions and applications.

This distinction underscores GEOAM's emphasis on evaluating the application of educational tools and initiatives for the purpose of promoting informed management practices. Such endeavors serve to underscore the inherent value of geo-inheritance within geosites and cultivate a culture of geoethics among the public. Consequently, this unique feature contributes to the methodology's effectiveness by examining the implementation of criteria in relation to the activities surrounding a geotope.

However, the consequence of this approach is reflected in the lower scores observed in the new methodology, highlighting the lack of systematic utilization of geosites in geoeducational processes at both individual and group levels. This underscores the imperative for direct interventions aimed at accentuating the educational dimension of geosites. By prioritizing education, knowledge transmission can be safeguarded, fostering geo-environmental empathy and promoting geo-ethical awareness. Ultimately, this holistic approach fosters sustainable development principles, ensuring the preservation and appreciation of natural heritage for future generations.

# Chapter 8: Promoting Geoeducation through GEOAM: Methodologies for Engagement and Impact

## 8.1. Introduction

As previously stated in the preceding chapter, geoeducation represents an invaluable instrument for promoting an understanding and awareness of the geological heritage, particularly in regions such as the Eastern Aegean islands, which are rich in geological features yet not readily accessible. The most effective method for the promotion of geoeducation is the GEOeducational Assessment Method (GEOAM). This chapter presents a realistic approach to the involvement of teachers and schools in the effective implementation of GEOAM, with the aim of enhancing geoeducation in Kalymnos, Nisyros, and Samos.

The principal objective is to establish a structured and realistic approach to the implementation of GEOAM in the educational system of Kalymnos, Nisyros, and Samos, with the specific aim of significantly enhancing geoeducation. By engaging relevant interest groups, obtaining the necessary resources, integrating the GEOAM approach into the curriculum, and providing comprehensive training, the basis for a successful implementation is established. The continuous evaluation and community involvement serve to reinforce the initiative, thereby ensuring its continued relevance and impact.

## 8.1. Training Plan for Implementing GEOAM

The successful implementation of the GEOeducational Assessment Method (GEOAM) in schools requires educators to receive an adequate level of training. The following plan delineates the structure and methodology to be employed in training educators to utilize the GEOeducational Assessment Method (GEOAM) effectively in an academic setting and to disseminate knowledge in the field of geoeducation.

### 8.1.1. Training Objectives

The training program has been designed with the following objectives, which will ensure a holistic understanding and effective implementation of the GEOeducational Assessment Method (GEOAM):

- ✓ To equip teachers with the knowledge and skills necessary to implement GEOAM.
- ✓ To foster an understanding of geoeducation and its importance.
- ✓ To provide hands-on experience with GEOAM tools and methods.
- ✓ To develop strategies for integrating GEOAM into the existing curriculum.

## 8.1.2. Training Components

### 8.1.2.1. Pre-Training Preparation

The initial phase of the pre-training preparation phase is the needs assessment. A survey will be conducted to gain insight into the current understanding and abilities of teachers and students with respect to the field of geo-education and the Geoeducational Assessment Method (GEOAM). This will facilitate an understanding of the extent to which the participants are familiar with the subject matter, their experience of similar methods and their confidence in implementing the GEOAM. The survey should encompass a range of topics, including familiarity with geo-educational concepts, experience with analogous methodologies, and confidence in the implementation of GEOAM. By identifying specific areas in which training is required, the program can be modified accordingly to address these gaps and ensure that all participants receive training which is relevant to their needs and effective for them.

After the needs assessment is completed, the next step is to develop the necessary training resources. This entails creating complete training materials, including manuals, guidelines, presentations, and digital resources, to serve as the base for training sessions. The resources must be comprehensive, user-friendly, and accessible, considering the intended audience's diverse learning abilities and preferences. In addition, a well-planned training program and agenda must be developed. The program schedule should include the topics to be covered, the estimated duration of each session, and the activities that must be carried out. This procedure ensures that training is scientific and systematic, allowing educators to steadily expand their understanding and skills in the implementation of GEOAM.

### 8.1.2.2. Training Program Structure

The GEOAM implementation training program was created to provide full coverage of all important themes, ensuring that educators are well-prepared to introduce geoeducation into the curriculum. The next part provides an outline of the training program's structure:

#### 1. Introduction to GEOAM.

This part includes an overview of GEOAM. The program begins with a review of GEOAM, including its specific aims and the reasons for its significance. The goal for teachers is to comprehend the framework and its role in improving geoeducation.

The concept of geoeducation will be introduced to participants, followed by an analysis of its relevance and possible influence on pupils. This seminar will also highlight the unique importance of geoeducation in the context of the Eastern Aegean.

#### 2. Understanding Geological Monuments

This training provides an overview of geological monuments and their potential educational applications. Teachers will learn about the many types of geosites and their importance to Kalymnos, Nisyros, and Samos islands. The goal is to establish in teachers an awareness for their community's geological heritage.

### 3. GEOAM Assessment Criteria

This part outlines the criteria for determining the implementation of the proposed method. It presents a thorough review of the GEOAM criteria and sub-criteria. Teachers will learn how to apply the GEOAM framework to assess the geoevaluational value of geosites. It contains suggestions and examples.

### 4. Practical Application of GEOAM

Hands-on training will illustrate GEOAM's practical applications. Teachers will utilize GEOAM tools and methodologies. The training will contain tasks designed to familiarize teachers with assessment. Field trips will be organized to allow teachers to try out GEOAM evaluations in the real world. GEOAM implementation will be practiced in a supportive setting through group activities and role-playing.

### 5. Integrating GEOAM into the Curriculum

GEOAM can be introduced into the curriculum using several techniques. Training will provide instructors with the skills they need to integrate GEOAM assessments into geography, geology, and environmental science courses by creating appropriate lesson plans that are flexible to different grade levels and prioritize hands-on learning.

### 6. Continuous Support and Professional Development

Mentorship programs offer guidance and support to new GEOAM members. This can be facilitated by pairing experienced teachers with new members. Mentors will assist new members in overcoming initial challenges and implementing excellent practices. An online portal will provide continuing support.

#### *8.1.2.3. Evaluation and Feedback*

A structured evaluation and feedback system is an essential component of any training program, as it enables the monitoring and improvement of quality and effectiveness. In the context of the GEOAM training program, this system is vital for ensuring that teachers are adequately prepared to implement GEOAM and promote geoevaluation in their respective schools. The following section presents a robust evaluation and feedback mechanism, which is crucial for ensuring the effectiveness and continuous improvement of the GEOAM training program.

#### 1. Monitoring and Assessment

Regular assessments will be undertaken to evaluate the training program's effectiveness. These will evaluate participants' understanding of GEOAM concepts, the ability to apply assessment criteria, and engagement with training materials.

Feedback will be collected so that it may be used to inform and improve the program. Participants' feedback will be obtained systematically via surveys, interviews, and focus groups. Particular attention will be paid to the participants' experiences, difficulties, and suggestions.

## 2. Adapting the Training Program

The program will be continuously refined based on feedback and assessment results. This will ensure the training remains relevant, engaging and effective. Modifications may include updating content, incorporating new examples and enhancing interactive components. These changes will be implemented systematically, including adjusting the training schedule, modifying workshop activities and introducing new support mechanisms. Regular reviews will ensure that these changes effectively address the needs of the participants and achieve the desired outcomes.

### 8.1.3. Detailed Training Schedule

The training schedule below was created with the goal of providing teachers with a complete and immersive learning experience that will provide them with the essential skills and knowledge to properly execute the GEOAM approach. The timetable is divided into three days, with each day covering a different topic of geoeducation and practical application. This structure guarantees that the training is comprehensive, giving instructors a well-rounded understanding of geoeducation theory and practice.

#### Day 1: Introduction and Foundations

The first day of training establishes the framework by exposing participants to the fundamental ideas of GEOAM and geoeducation. It combines lectures, interactive discussions, and hands-on workshops to ensure a complete understanding of the fundamental concepts.

9:00 AM - 10:00 AM: Welcome and Introduction

- ✓ Overview of training objectives and agenda
- ✓ Introduction to GEOAM and the importance of geoeducation

10:00 AM - 12:00 PM: Understanding Geosites

- ✓ Lecture on the significance of geosites
- ✓ Case studies of local geosites to contextualize learning

12:00 PM - 1:00 PM: Lunch Break

1:00 PM - 3:00 PM: GEOAM Assessment Criteria

- ✓ Detailed explanation of GEOAM criteria and sub-criteria
- ✓ Interactive discussion and Q&A session to clarify doubts

3:00 PM - 5:00 PM: Practical Application Workshop

- ✓ Hands-on exercises using GEOAM tools
- ✓ Group activities and role-playing to simulate real-world scenarios

### Day 2: Field Trip and Hands-on Training

The second day is dedicated to practical, field-based training, allowing participants to apply what they have learned in a real-world context. This day is critical for applying theoretical information through practical application.

9:00 AM - 12:00 PM: Field Trip to Local Geosite

- ✓ Practical assessment of a local geosite using GEOAM
- ✓ Group discussions and feedback sessions to consolidate learning

12:00 PM - 1:00 PM: Lunch Break

1:00 PM - 3:00 PM: Integrating GEOAM into the Curriculum

- ✓ Strategies for incorporating GEOAM assessments into existing curricula
- ✓ Development of lesson plans and student projects using GEOAM

3:00 PM - 5:00 PM: Extracurricular Activities and Community Involvement

- ✓ Planning for geoeducation clubs and community projects
- ✓ Interactive session on engaging the community in geoeducation initiatives

### Day 3: Continuous Support and Evaluation

The third day highlights the need for continued assistance and evaluation to ensure the long-term viability of GEOAM use. It contains plans for ongoing professional growth, as well as effective monitoring and assessment procedures.

9:00 AM - 11:00 AM: Continuous Support Strategies

- ✓ Establishment of mentorship programs and online support platforms
- ✓ Planning for follow-up workshops and refresher courses

11:00 AM - 12:00 PM: Monitoring and Assessment

- ✓ Methods for evaluating the effectiveness of GEOAM implementation
- ✓ Techniques for collecting and utilizing feedback to improve the program

12:00 PM - 1:00 PM: Lunch Break

1:00 PM - 3:00 PM: Final Workshop and Certification

- ✓ Final hands-on exercises and role-playing activities to reinforce learning
- ✓ Certification ceremony for participants who have successfully completed the training

3:00 PM - 5:00 PM: Open Forum and Closing Remarks

- ✓ Open forum for participants to share experiences, insights, and feedback
- ✓ Closing remarks and discussion of next steps for continued engagement and support

## Chapter 9: Assessing Geoeducation in Secondary Schools: A Statistical Study of Kalymnos and Nisyros

The primary objective of this chapter is to evaluate the impact of the geoeducation training program on the understanding and interest of students and teachers. To achieve this objective, a pre-test will be administered to assess students' and teachers' initial awareness and understanding of geosites, geoparks and geological heritage. Subsequently, and following the implementation of relevant training in teaching the basic principles of geo-education within GEOAM with an emphasis on the importance of geo-heritage and sustainable environmental practices, a test will be administered to evaluate the effectiveness of the program in terms of improving students' and teachers' understanding of geo-education concepts and their willingness to expand their knowledge in this area.

The Ministry of Education and the Dodecanese Secondary Directorate approved this study, assuring that ethical criteria were met, particularly given the involvement of minor students.

The study encompassed all junior high school units on the islands of Kalymnos (three schools) and the only junior high school on Nisyros. This method produced a highly representative sample that reflected the views of the full relevant population of students and instructors in these areas. Participants were informed of their rights to refuse to answer any of the questions, respecting their individual rights and making the questionnaire optional.

The total participation rate was as follows:

- Pupils: 444 out of 672 (66.07%)
- Teachers: 55 out of 94 (58.5%)

Two participants didn't clarify whether they were students or teachers. Additionally, only two schools topped 50% participation in both categories (students and instructors). A particular school unit had the lowest teacher participation percentage (23.5%), while another had the lowest student participation rate (50%).

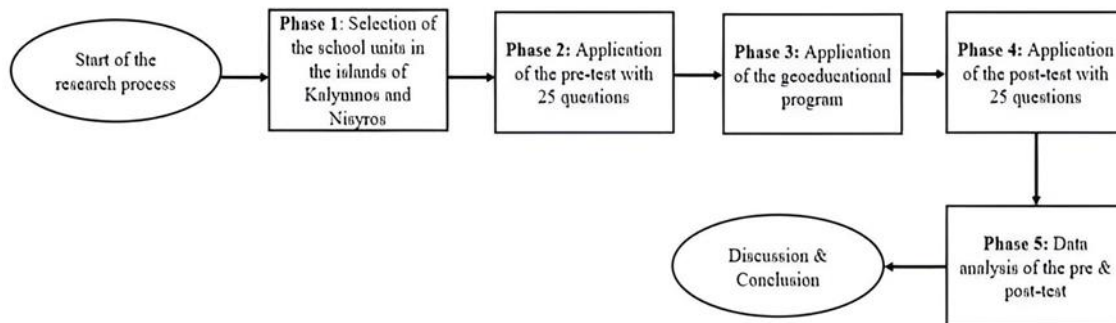
Samos Island was not included in this study due to logistical difficulties and special circumstances that precluded the inclusion of its school units. These challenges include difficulties acquiring appropriate permissions, coordination issues with local educational authorities, and practical constraints associated with questionnaire distribution and collecting. The special focus on Kalymnos and Nisyros allowed for a more manageable and concentrated evaluation of geoeducation on these islands, resulting in an exhaustive and representative assessment within the given resources and timescale. Future research could add Samos to provide a more complete picture of geoeducation throughout all non-profit line islands in the Eastern Aegean Sea.

## 9.1. Methodology

To achieve the objectives, a mixed methodological approach was employed (**Figure 44**), integrating qualitative and quantitative research techniques. The objective of the qualitative research was to gather detailed information on the participants' understanding, attitudes and perceptions in relation to geoeducation.

Purposive sampling was employed to select a diverse group of 30 participants, comprising secondary school teachers, students and community members from Kalymnos and Nisyros. The diversity of the sample enabled the capture of a wide range of views on geo-education. Focus groups and semi-structured interviews were used to acquire primary data. The semi-structured interviews provided an opportunity for participants to express their thoughts on geo-education and its local significance. Focus groups were organized to facilitate debate and idea exchange. These exchanges provided insight into views regarding geoscience education. The interviews and focus groups were transcribed and thematically analyzed. Several major topics emerged from the investigation, including awareness of geoscience education, perceived challenges to incorporating it into the school curriculum, and possible advantages for communities. These topics proved useful in developing the questions for the upcoming quantitative analysis.

The qualitative phase helped to shape the quantitative study strategy by revealing specific areas of interest and concern. For example, qualitative data revealed a lack of expertise with certain geoeducation terminology. This prompted the questionnaire to include comprehension-related questions. Insights into views about environmental stewardship and geotourism were used to focus the poll on these components of geoeducation.



**Figure 44.** Flow chart defining the basic phases of the research

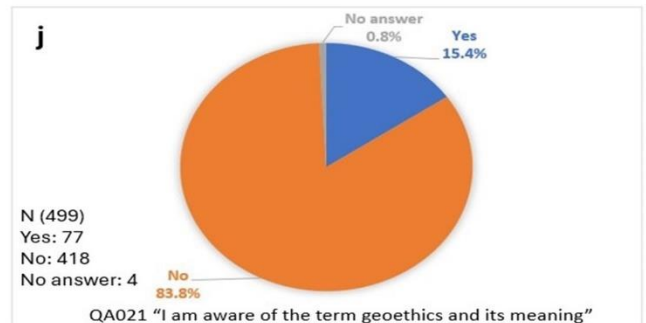
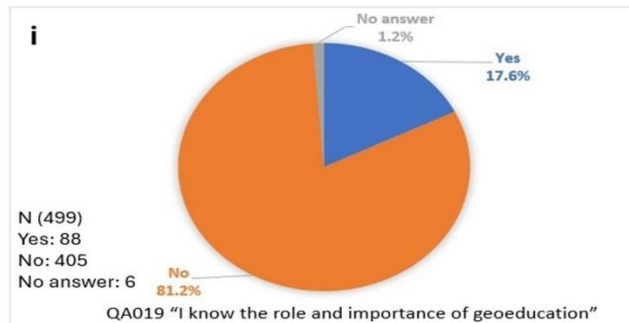
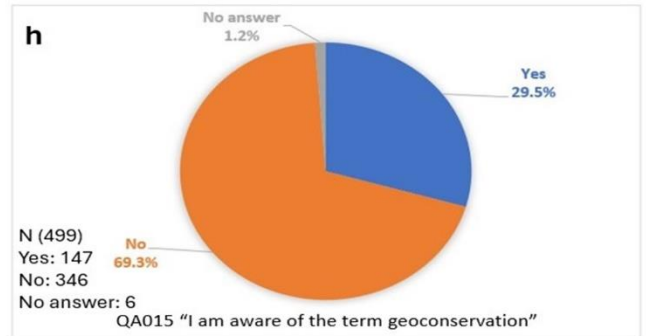
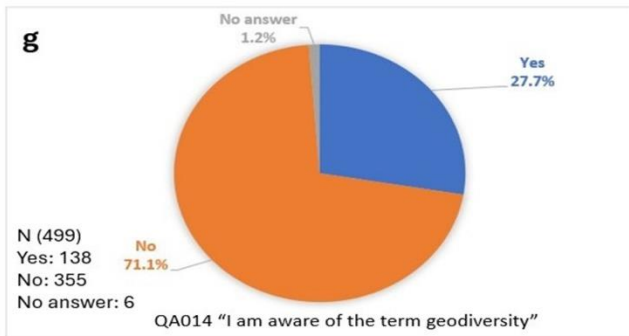
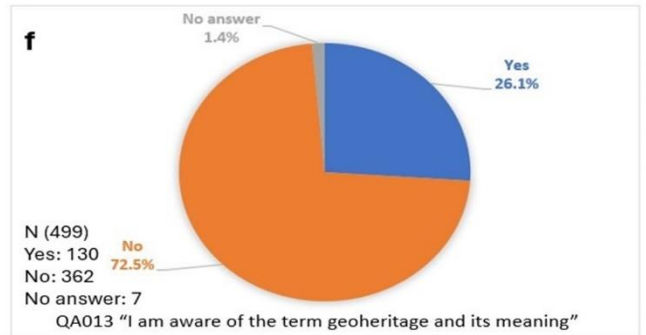
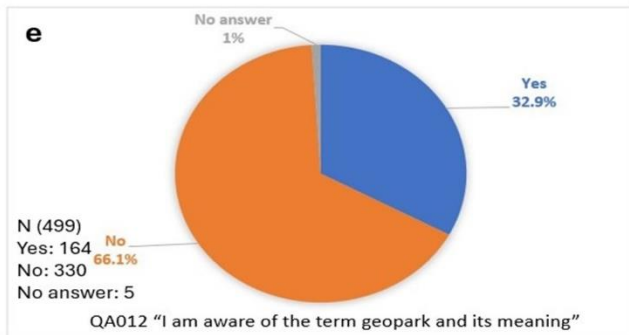
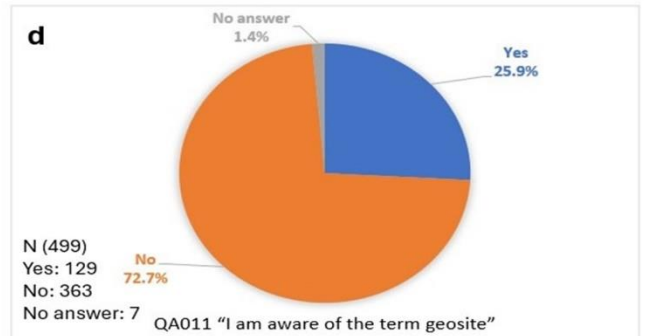
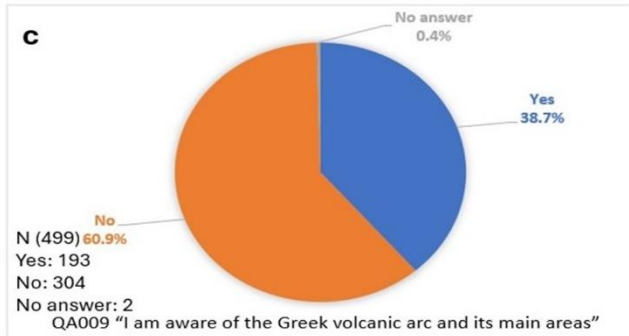
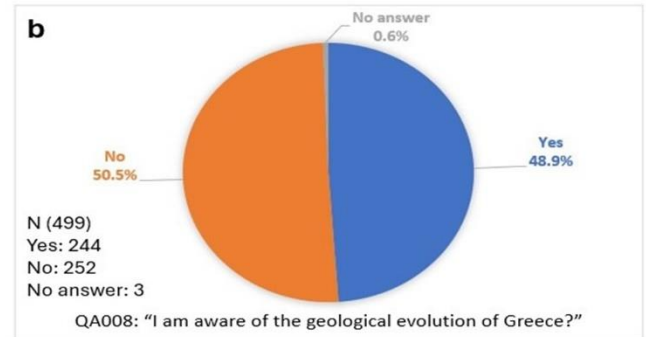
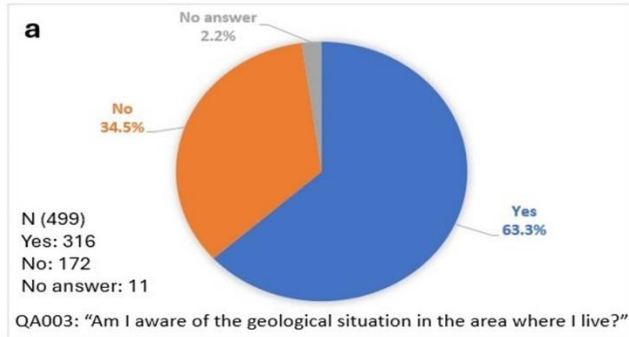
## 9.2 Application of pre-test (Questionnaire A)

The pre-test questionnaire (QA) included 25 questions, designed to measure knowledge of basic geological concepts and geosites. The findings from the 499 participants are summarized below (**Appendix D**):

1. Awareness of Local Geological Conditions (QA003) (as shown in **Figure 45a**):
  - a. 316 participants (63.30%) were aware of the geological situation of their area.
  - b. 172 participants (34.50%) were not aware.
  - c. 11 participants (2.20%) did not respond.
2. Visits to geologically significant areas (QA004):
  - a. 290 participants (58.10%) visited areas with significant geological features.
  - b. 204 participants (40.90%) did not visit these areas.
  - c. 5 participants (1.00%) did not respond.
3. Sources of Geological Knowledge (QA005):
  - a. 171 participants (34.30%) learned from geology books.
  - b. 62 participants (12.40%) learned from history books.
  - c. 54 participants (10.80%) learned from other literature sources.
  - d. 209 participants (41.90%) had no knowledge.
  - e. 3 participants (0.60%) did not respond.
4. Instructor's Specialty for Geology Course (QA006):
  - a. 249 participants (49.90%) reported that the geology course was taught by a geologist.
  - b. 76 participants (15.20%) reported it was taught by a physicist.
  - c. 34 participants (6.80%) reported it was taught by a chemist.
  - d. 92 participants (18.40%) reported it was taught by a biologist.
  - e. 45 participants (9.00%) reported it was taught by another specialty.
  - f. 3 participants (0.60%) did not respond.
5. Participation in Educational Programs (QA007):
  - a. 82 participants (16.40%) participated in a school geoenvironmental educational program.
  - b. 115 participants (23.00%) had participated in other educational programs.
  - c. 62 participants (12.40%) participated in extracurricular environmental programs.
  - d. 238 participants (47.80%) had not participated in any environmental or educational programs.
  - e. 2 participants (0.40%) did not respond.
6. Knowledge of Geological Evolution of Greece (QA008) (as depicted in **Figure 45b**):
  - a. 244 participants (49.90%) had knowledge of the geological evolution of Greece.
  - b. 252 participants (50.50%) did not have this knowledge.
  - c. 3 participants (0.60%) did not respond.
7. Awareness of Greek Volcanic Arc (QA009) (as demonstrated in **Figure 45c**):
  - a. 193 participants (38.70%) were aware of the Greek volcanic arc and its main areas.
  - b. 304 participants (60.90%) were not aware.
  - c. 2 participants (0.40%) did not respond.
8. Reasons for Greece's Seismicity (QA010):
  - a. 53 participants (10.60%) attributed seismicity to volcanoes.

- b. 53 participants (10.60%) attributed it to climatic conditions.
  - c. 339 participants (67.90%) attributed it to the convergence of lithospheric plates.
  - d. 48 participants (9.70%) attributed it to rocks.
  - e. 6 participants (1.20%) did not respond.
9. Awareness of the Term ‘Geosite’ (QA011) (as presented in **Figure 45d**):
- a. 129 participants (25.90%) were aware of the term ‘geosite’.
  - b. 363 participants (72.70%) were not aware.
  - c. 7 participants (1.40%) did not respond.
10. Awareness of the Term ‘Geological Park’ (QA012) (as indicated in **Figure 45e**):
- a. 164 participants (32.90%) were aware of the term ‘geological park’.
  - b. 330 participants (66.10%) were not aware.
  - c. 5 participants (1.00%) did not respond.
11. Awareness of the Term ‘Geoheritage’ (QA013) (as demonstrated in **Figure 45f**):
- a. 130 participants (26.10%) were aware of the term ‘geoheritage’.
  - b. 362 participants (72.50%) were not aware.
  - c. 7 participants (1.40%) did not respond.
12. Awareness of the Term ‘Geodiversity’ (QA014) (as evidenced in **Figure 45g**):
- a. 138 participants (27.70%) were aware of the term ‘geodiversity’.
  - b. 355 participants (71.10%) were not aware.
  - c. 6 participants (1.20%) did not respond.
13. Awareness of the Term ‘Geoconservation’ (QA015) (as shown in **Figure 45h**):
- a. 147 participants (29.50%) were aware of the term ‘geoconservation’.
  - b. 346 participants (69.30%) were not aware.
  - c. 6 participants (1.20%) did not respond.
14. Knowledge of Geological Parks in Greece (QA016):
- a. 225 participants (45.10%) knew how many geological parks Greece has.
  - b. 268 participants (53.70%) did not know.
  - c. 6 participants (1.20%) did not respond.
15. Awareness of Sustainable Development (QA017):
- a. 221 participants (44.30%) were aware of the term ‘sustainable development’ and its benefits.
  - b. 275 participants (55.10%) were not aware.
  - c. 3 participants (0.60%) did not respond.
16. Knowledge of Geoeducation (QA018):
- a. 82 participants (16.40%) had heard of geoeducation.
  - b. 415 participants (83.20%) did not.
  - c. 2 participants (0.40%) did not respond.
17. Understanding the Role of Geoeducation (QA019) (as illustrated in **Figure 45i**):
- a. 88 participants (17.60%) understood the role and importance of geoeducation.
  - b. 405 participants (81.20%) did not.

- c. 6 participants (1.20%) did not respond.
- 18. Awareness of Geoeducational Activities (QA020):
  - a. 64 participants (12.80%) were aware of various geoeducational activities.
  - b. 430 participants (86.20%) were not aware.
  - c. 5 participants (1.00%) did not respond.
- 19. Awareness of Geoethics (QA021) (as depicted in **Figure 45j**):
  - a. 77 participants (15.40%) were aware of the term 'geoethics' and its meaning.
  - b. 418 participants (83.80%) were not aware.
  - c. 4 participants (0.80%) did not respond.
- 20. Belief in Geoeducation's Societal Contribution (QA022):
  - a. 211 participants (42.30%) believed that geoeducation can positively contribute to society.
  - b. 276 participants (55.30%) did not believe so.
  - c. 12 participants (2.40%) did not respond.
- 21. Engagement in Geoeducational Activities (QA023):
  - a. 102 participants (20.40%) were engaged in geoeducational activities.
  - b. 396 participants (79.40%) were not.
  - c. 1 participant (0.20%) did not respond.
- 22. Knowledge of Geological Parks and Locations (QA024):
  - a. 80 participants (16.00%) knew how many geological parks Greece has and their locations.
  - b. 417 participants (83.60%) did not know.
  - c. 2 participants (0.40%) did not respond.
- 23. Connection Between Geoeducation and Cultural Values (QA025):
  - a. 306 participants (61.30%) believed that geoeducation relates to cultural or archaeological values.
  - b. 190 participants (38.10%) did not believe so.
  - c. 3 participants (0.60%) did not respond.



**Figure 45.** Pie charts summarizing the awareness of 499 participants (N=499) on various terms and concepts related to geoeducation. Key findings include that 63.3% of participants were aware of the local geological situation, but awareness of other geoscience concepts, such as geological evolution, geosites, geoheritage, and geoeeducation, was significantly lower, indicating a general lack of knowledge in these areas.

In general, a lack of understanding of concepts and terms considered basic geological knowledge was found.

It is also important to note that the pupils showed a greater willingness to participate than teachers. Specifically, 65.77% of pupils participated, while only 58.50% of teachers did. This relatively low participation rate among teachers highlights a potential issue. It indicates a possible reluctance or lack of awareness of the importance of a geoeeducational program and the concepts it addresses.

Regarding the answers of the pre-test, 34.50% of participants did not know the fundamental geological issues in their region. In addition, four out of ten participants had not visited areas of intense geological interest located in their place of residence. This indicates a lack of rational and collective utilization of such areas, which could benefit from appropriate promotion. Local bodies should engage in various promotional activities with the local community. Only in this way can sites with strong geological features become attractions for visitors, offering not only basic tourist services but also recreational opportunities.

In addition, the teaching of geology is mainly carried out by staff from other disciplines. More specifically, 50.10% of the participants stated that the course is not taught by a geologist. This is perhaps the most concerning finding of the study, as it has important implications for the transfer of knowledge about geoeeducation and the promotion of geoethical values. Therefore, the Ministry of Education should ensure a higher percentage of geologists in school units nationwide, especially in areas of strong geo-logical interest

More than 50% of the participants did not know the geological evolution of Greece or the Greek volcanic arc and its location. In addition, terms such as geoconservation, geological park, geolandscape, geodiversity, geoheritage and geoethics were unknown to over 60% of participants, while in some cases this percentage exceeded 70%. This lack of awareness demonstrates the need for a major revision of school textbooks related not only to the teaching of geology but also to the broader geosciences or environmental education.

### 9.3. GEOAM Training and Post-Test Implementation

After carrying out the pre-test and identifying the cognitive deficits of the teachers and students, an attempt was made to implement the training program. Due to objective difficulties, which can be summarized as a plethora of bureaucratic procedures and lack of time, it was not possible to carry out the three-day seminar. Nevertheless, informative lectures, a visit to the geological monuments of Kalymnos, their evaluation with GEOAM and the implementation of an

educational program about caves were carried out. This integration enhances participants' understanding of geoheritage and geoconservation, while utilizing GEOAM as a practical evaluation tool to assess geological sites.

In the first phase of the training, participants are introduced to geological concepts through interactive presentations and visual aids. At this stage, GEOAM can be integrated as part of the theoretical curriculum. Alongside the introduction to geological formations, such as cave systems and other geomorphological features, participants are trained in how to use the GEOAM method. They learn how to systematically evaluate geosites, understanding the criteria for assessing educational, cultural, and environmental significance.

The geoeucational program, titled "Exploring the Wonderful World of a Limestone Island," focuses on the geology of Kalymnos and engages high school students and teachers with classroom-based learning (Zafeiropoulos et al., 2021). This program is enhanced by introducing the GEOAM method, which provides a structured approach to evaluating the island's geological monuments. The combined learning process establishes a strong foundation in both geoeucation and site evaluation techniques, preparing participants for practical application during fieldwork.

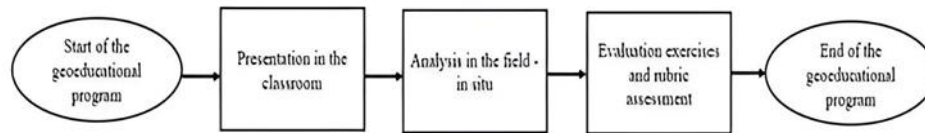
During the second phase of the geoeucational program (Figure 46), participants embark on field visits to geological sites. This field analysis phase is essential for translating theoretical knowledge into practical experience. Here, students and teachers use the GEOAM tool to evaluate the sites they visit, such as caves and other significant geological formations on Kalymnos. Equipped with tablets and digital tools, participants input their observations into GEOAM, assessing the geosites based on predefined criteria.

Field analysis also encourages collaborative learning. Participants work together to apply GEOAM, fostering critical thinking, problem-solving, and teamwork. By combining the field experience with GEOAM's practical application, participants are not only able to assess the geoeucational value of the sites, but also enhance their understanding of the geological processes behind these formations.

After the field visits, the program moves into its final phase, where participants return to the classroom for reflective activities. In this phase, GEOAM is revisited, and participants engage in discussions about their experiences using the method in real-world contexts. This reflection allows them to analyze the strengths and limitations of GEOAM, identifying areas where it can be most effective in assessing educational value, public engagement, and societal implementation of geosites.

To reinforce the knowledge gained, participants complete exercises, including true/false and multiple-choice questions about the geological concepts (Appendix E). These exercises help solidify their understanding of geoeucation principles and site evaluation techniques. Additionally, a hidden word puzzle and a detailed cave system diagram are used to review key terms and concepts in a fun, interactive way.

At the conclusion of the program, participants evaluate the program using a rubric that includes criteria such as understanding of geological concepts, increased awareness of geoenvironmental protection, and promotion of sustainable development. This evaluation includes feedback specifically focused on the effectiveness of GEOAM training, assessing how well participants understood and applied the tool during their fieldwork.



**Figure 46.** Flow chart of the geoeucational program

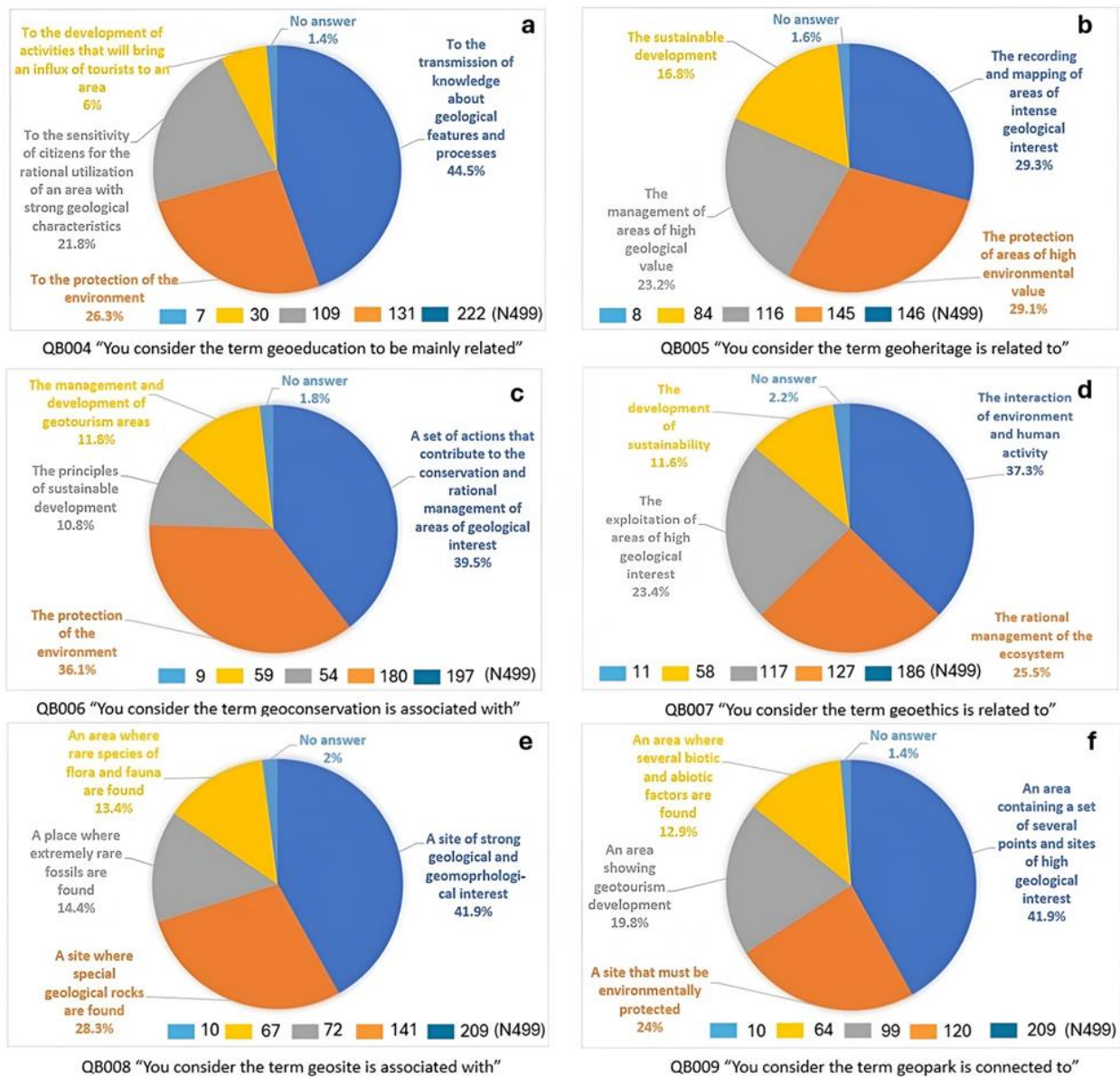
Due to the initial unawareness of teachers and pupils about basic geological topics as revealed by the pre-test, it is now appropriate to implement the post-test to measure the impact of the training schedule. The post-test consists of 25 questions, like the pre-test. It initially examines whether the participants have understood the basic geological concepts promoted by our geoeucational program (questions QB04 to QB09). The remaining questions aim to capture the participants' opinions on the conceptual framework and the activities introduced through the geoeucational program.

The post - test included 25 questions (**Appendix F**), with the first two questions being the same as those of the pre - test. The post - test was conducted after the geoeucation program and aimed to assess whether there was a positive response and improved understanding of geoeucation and its conceptual framework. The findings from the 499 participants are as follows:

1. Development and Spread of Geoeducation (QB003):
  - a. 259 participants (51.90%) believed geoeucation would develop through intra-mural activities and similar programs.
  - b. 48 participants (9.60%) thought it would be promoted through a document outlining its meaning and dimensions.
  - c. 91 participants (18.20%) felt it would be spread through extracurricular geoenvironmental activities.
  - d. 92 participants (18.50%) believed it would be advanced through municipal or local community initiatives.
  - e. 9 participants (1.80%) did not respond.
2. Primary Association of Geoeducation (QB004) (as demonstrated in **Figure 47a**):
  - a. 222 participants (44.50%) related geoeucation primarily to the transmission of knowledge about geological features and processes.
  - b. 131 participants (26.30%) associated it with environmental protection.
  - c. 109 participants (21.80%) connected it to fostering sensitivity for the rational utilization of areas with significant geological characteristics.
  - d. 30 participants (0.60%) related it to developing activities that attract tourists.

- e. 7 participants (1.40%) did not respond.
3. Understanding of Geoh heritage (QB005) (as presented in **Figure 47b**):
  - a. 146 participants (29.30%) associated geoh heritage with recording and mapping areas of intense geological interest.
  - b. 145 participants (29.10%) linked it to the protection of areas with high environmental value.
  - c. 116 participants (23.20%) connected it to the management of areas of high geological value.
  - d. 84 participants (16.80%) related it to sustainable development.
  - e. 8 participants (1.60%) did not respond.
4. Association of Geoconservation (QB006) (as indicated in **Figure 47c**):
  - a. 197 participants (39.50%) saw geoconservation as a set of actions for the conservation and rational management of geological areas.
  - b. 180 participants (36.10%) associated it with environmental protection.
  - c. 54 participants (10.80%) linked it to sustainable development principles.
  - d. 59 participants (11.80%) connected it to the management and development of geotourism areas.
  - e. 9 participants (1.80%) did not respond.
5. Understanding of Geoethics (QB007) (as evidenced in **Figure 47d**):
  - a. 186 participants (37.30%) associated geoethics with the interaction between the environment and human activity.
  - b. 127 participants (25.50%) related it to the rational management of the ecosystem.
  - c. 117 participants (23.40%) connected it to the exploitation of high geological interest areas.
  - d. 58 participants (11.60%) associated it with the development of sustainability.
  - e. 11 participants (2.20%) did not respond.
6. Definition of a Geosite (QB008) (as shown in **Figure 47e**):
  - a. 209 participants (41.90%) described a geosite as a location of significant geological and geomorphological interest.
  - b. 141 participants (28.30%) identified it as a site with special geological rocks.
  - c. 72 participants (14.40%) considered it a place with extremely rare fossils.
  - d. 67 participants (13.40%) thought it was an area with rare flora and fauna species.
  - e. 10 participants (2.00%) did not respond.
7. Concept of a Geopark (QB009) (as illustrated in **Figure 47f**):
  - a. 209 participants (41.90%) viewed a geopark as an area with a collection of sites of high geological interest.
  - b. 120 participants (24.00%) thought it must be environmentally protected.
  - c. 99 participants (19.80%) associated it with geotourism development.
  - d. 64 participants (12.90%) considered it an area with various biotic and abiotic factors.

- e. 7 participants (1.40%) did not respond.
- 8. Most Important Sector for Geoeducation (QB010):
  - a. 255 participants (51.10%) prioritized geoscientific knowledge.
  - b. 170 participants (34.06%) emphasized awareness of natural disasters.
  - c. 128 participants (25.65%) focused on the rational use of mineral wealth.
  - d. 96 participants (19.23%) highlighted awareness of sustainable development and its applications.
    - e. 206 participants (41.28%) valued awareness of geoheritage.
    - f. 231 participants (46.29%) considered awareness of geoconservation and environmental protection most important.
    - g. 116 participants (23.24%) prioritized awareness of geoethics and its beneficial dimensions.
      - h. 7 participants (1.40%) did not respond.
- 9. Definition of Geotourism (QB011):
  - a. 233 participants (46.90%) viewed geotourism as focusing on geoeducational activities and visiting areas of high geological value.
  - b. 130 participants (26.10%) saw it as alternative tourism activities.
  - c. 69 participants (13.80%) associated it with the development of tourism infrastructure.
    - d. 55 participants (12.00%) thought it involved activities for environmental protection.
      - e. 7 participants (1.40%) did not respond.
- 10. Opinions about geoeducation (QB012 to QB025): Participants rated their opinions on these questions using a Likert scale (1-5). Overall, the mean scores for most questions ranged from 3.4 to 4.0. The exception was question QB012, which had a mean value of 2.1.



**Figure 47.** Pie charts illustrating the understanding of geoeeducation and related terms among the 499 participants (N=499). The majority (44.5%) associate geoeeducation with knowledge of geological features, while 26.3% associate it with environmental protection. Responses to geoheritage, geo-conservation, geoethics, geosites, and geoparks indicate a significant awareness of the importance of conservation, ethical management, and education about sites of geological interest. It is worth noting that the results of the post - test showed improved accuracy after the implementation of the geo-educational program.

After completing the geoeeducation program and training participants, both students and teachers demonstrated a solid grasp of the core concepts related to geoeeducation. Students showed enthusiasm, engaging actively by asking numerous questions during the program. The integration of digital tools, such as computers, tablets, and video projectors, was pivotal in enhancing the learning experience. These tools allowed participants to visually identify and interact with key geological features in real-time, making the learning process more dynamic and contributing

significantly to their understanding of various geological terms. This underscores the interdisciplinary nature of geoeducation.

In addition to the geoeducational program, participants also received training in the GEOAM (Geoeducational Assessment Method), which further enriched their understanding of geoheritage. The GEOAM training helped participants apply theoretical knowledge to practical settings, reinforcing concepts like geoconservation, geoethics, and sustainable development. The use of GEOAM also emphasized the importance of evaluating geosites, fostering a deeper appreciation of geological features and their societal value.

The results from the post-test showed a marked improvement in participants' comprehension of these topics. Most participants were able to articulate the connections between geoconservation, geoparks, geoheritage, geodiversity, and geoethics, and they provided thoughtful responses about how these concepts align with sustainable development and benefit the local community. Notably, question QB 018 in the post-test received the highest average score ( $M*(N499) = 4.0$ ), indicating a strong consensus that geoeducation can contribute to the economic growth of a region through sustainable development initiatives.

## Chapter 10: Future perspectives

### 10.1 Discussion

The development and application of the GEOeducational Assessment Method (GEOAM) have significantly contributed to answering the research questions of this study in several ways:

#### 10.1.1. Research Question 1: What is the current state of geoeducation in the Eastern Aegean islands, specifically in Kalymnos, Nisyros, and Samos?

There is a lack of awareness of geoeducation in Kalymnos, Nisyros and Samos. There is a lack of geoeducation in the school curriculum. The IEP needs to revise the geology/geography textbooks to help students grasp relevant concepts and promote geo-ethical awareness. Teachers of geology/geography or environmental education also need to be trained in geoeducation. Local societies on these islands currently provide a limited geo-education service.

More comprehensive initiatives are needed to promote geoeducation. Effective strategies include cooperation between local agencies and universities, and outreach to policymakers, stakeholders and residents. Some geosites in these islands show high geoeducation potential, but the approach is inconsistent. Resource constraints, limited community engagement and sporadic educational initiatives hinder geoeducation promotion. Despite challenges, there are opportunities to improve geoeducation by developing model programs in high-potential geosites and using the GEOAM methodology. Integrating geoeducation with cultural and archaeological values makes it more attractive and relevant. Partnerships with local experts and educational institutions can address existing challenges, fostering a deeper understanding and appreciation of the geological heritage of the Eastern Aegean islands. .

#### 10.1.2. Research Question 2: How effective are the existing geoheritage assessment methods (e.g., Brilha's method and M-GAM) in evaluating the geoeducational potential of geosites?

The existing geomorphosite assessment methods, including Brilha's method and the M-GAM, exhibit varying degrees of effectiveness in evaluating the geoeducational potential of geosites in Kalymnos, Nisyros, and Samos. Brilha's method provides a comprehensive analysis of geosites by considering diverse geological and educational attributes, making it strong in evaluating representativeness and exemplariness. However, it falls short in capturing the practical, on-the-ground educational activities and their societal impact. The M-GAM method, on the other hand, incorporates visitor perspectives, offering a unique insight into the non-expert view of

geosites. This adds value in understanding public engagement and perceived educational potential, yet it lacks a strong focus on specific educational criteria and structured educational processes.

Both methods exhibit strengths in their holistic approaches but have limitations when it comes to specific geoeducational dimensions. Brilha's method emphasizes scientific and intrinsic values, often neglecting the practical application of geoeducation in communities and schools. M-GAM's inclusion of public perception is beneficial but does not fully address the structured educational frameworks needed for effective geoeducation. Neither method sufficiently incorporates societal implementation measures, such as community engagement strategies or educational program development. The newly introduced GEOAM method, with its specific sub-criteria for educational applications, fills this gap by focusing on the actual use of geosites in educational contexts and promoting sustainable management practices. This underscores the need for a more integrated approach that combines the strengths of existing methods with a robust framework for educational and societal implementation.

### 10.1.3. Research Question 3: What is the GEOeducational Assessment Method (GEOAM), and how does it differ from traditional geoheritage assessment methods?

The GEOeducational Assessment Method (GEOAM) is a novel approach designed to evaluate the geoeducational value of geosites, distinguishing itself from traditional geomorphosite assessment methods by its focused criteria on educational applications. Unlike conventional methods such as Brilha's and M-GAM, which assess geosites based on a range of geological and aesthetic values with limited emphasis on educational aspects, GEOAM specifically targets the educational potential and practical use of geosites in educational contexts. This method incorporates criteria that emphasize the implementation of educational tools, the potential for knowledge transmission, and the promotion of geo-ethical awareness.

GEOAM employs a set of criteria and sub-criteria tailored to evaluate the educational value of geosites comprehensively. These criteria include the site's representation of geological features, its accessibility and safety for educational activities, the presence of interpretive materials, and the infrastructure supporting educational visits. Sub-criteria focus on the specific educational applications, such as the quality of educational programs, the involvement of schools and local communities, the site's ability to facilitate experiential learning, and the degree of public engagement. By addressing these aspects, GEOAM ensures a thorough assessment of how effectively a geosite can be used for educational purposes, promoting a deeper understanding of geological processes and fostering a culture of geo-environmental empathy and sustainable development.

#### 10.1.4. Research Question 4: How do the geosites in Kalymnos, Nisyros, and Samos islands perform when evaluated using GEOAM compared to traditional methods?

The evaluation of geosites in Kalymnos, Nisyros, and Samos using the GEOeducational Assessment Method (GEOAM) reveals significant insights into their educational potential, distinct from traditional methods. GEOAM focuses on educational criteria, assessing aspects such as the site's capacity for educational programs, infrastructure for learning activities, and public engagement. The key findings indicate that many geosites have substantial educational value but often lack systematic utilization for geoeducational purposes. The scores from GEOAM highlight areas needing direct interventions to enhance educational dimensions, such as improved interpretive materials and stronger community involvement in educational activities.

When compared to traditional methods like Brilha's and M-GAM, GEOAM results show notable differences. Traditional methods primarily assess geosites based on their geological, aesthetic, and scientific values, with less emphasis on educational applications. For instance, Brilha's method focuses on comprehensive geological and conservation values, while M-GAM incorporates visitor perspectives but lacks specific educational criteria. In contrast, GEOAM's scores tend to be lower, reflecting the gap in systematic educational implementation despite the inherent potential. This discrepancy underscores GEOAM's unique contribution by emphasizing the need for educational tools and initiatives, which are not fully captured by the other methods. The comparison demonstrates GEOAM's effectiveness in identifying educational opportunities and challenges, providing a clearer path for enhancing geoeducation at these geosites.

#### 10.1.5. Research Question 5: What are the potential benefits of integrating geoeducation and geotourism in promoting sustainable development on remote islands?

The thesis effectively addressed the question of the potential benefits of integrating geoeducation and geotourism in promoting sustainable development on remote islands. Through a detailed analysis of the educational and geotourism practices in Kalymnos, Nisyros, and Samos, it demonstrated how geoeducation raises geoethical awareness by providing locals and tourists with knowledge about geological heritage and the importance of conservation. By incorporating geoeducational activities in local schools and communities, the study highlighted how educational initiatives can foster sustainable practices and environmental stewardship.

Additionally, the thesis explored the role of geotourism in enhancing the economic and cultural vitality of the islands. It showed that geotourism not only attracts visitors interested in geological features but also generates revenue and creates employment opportunities in the local economy. The comparative analysis of various assessment methods, including the newly developed GEOeducational Assessment Method (GEOAM), illustrated how incorporating educational dimensions into geosite evaluations can enhance the effectiveness of geotourism

strategies. This integrated approach ensures that the promotion of geotourism aligns with sustainable development goals, preserving natural heritage and fostering cultural exchange and local pride.

#### 10.1.6. Research Question 6: What strategies can be developed to enhance the implementation of geoeducation and geotourism in the Eastern Aegean islands?

Strengthening community engagement and capacity building is crucial for the future of geoeducation and geotourism in the Eastern Aegean islands. Empowering local communities to lead geoeducation and geotourism projects by providing training and resources can foster a deeper connection to the geological heritage and ensure initiatives are culturally relevant and sustainable. Establishing regional networks that bring together stakeholders from local communities, educational institutions, government agencies, and tourism operators can facilitate knowledge sharing, best practices, and collaborative projects that enhance geoeducation and geotourism.

Innovative educational programs and tools are essential to making geoeducation accessible and engaging. Developing comprehensive digital platforms that offer virtual tours, interactive maps, and educational resources can make geoeducation accessible to a broader audience, including remote learners and tourists planning their visits. Integrating augmented reality (AR) and virtual reality (VR) technologies into geoeducational experiences can create immersive and engaging learning environments, bringing the geological history and features of geosites to life and making them more relatable and understandable for visitors.

Integrating geoeducation into formal education can ensure long-term sustainability and impact. Advocating for the inclusion of geoeducation in the formal education curriculum at all levels through partnerships with educational authorities and the development of standardized educational modules focused on geology and geoheritage is essential. Implementing specialized training programs for teachers to equip them with the knowledge and skills needed to teach geoeducation effectively, including field-based learning experiences and the use of digital tools in the classroom, can further enhance the effectiveness of geoeducation.

Sustainable geotourism development should be a priority. Promoting the development of eco-friendly infrastructure at geosites, such as sustainable trails, visitor centers, and accommodation options, can minimize environmental impact while enhancing the visitor experience. Encouraging geotourism operators to adopt sustainable practices, such as limiting visitor numbers to prevent over-tourism, promoting low-impact activities, and educating tourists on environmental stewardship and geo-ethical principles, is also crucial.

Research and monitoring are essential for the continuous improvement of geoeducation and geotourism initiatives. Conducting regular assessments of the effectiveness of geoeducation and geotourism initiatives by collecting feedback from participants, monitoring environmental impacts, and evaluating educational outcomes can provide valuable insights. Fostering

collaborations between researchers, geoscientists, and educators to explore new approaches to geoeducation and geotourism can lead to the development of innovative methods and tools that enhance the educational value and sustainability of geosites.

By pursuing these strategies, the Eastern Aegean islands can continue to develop their geoeducational and geotourism potential, contributing to sustainable development and the preservation of their unique geological heritage.

#### 10.1.7. Research Question 7: How do the findings of this research contribute to the broader goals of geoheritage conservation and sustainable development as outlined by UNESCO's Sustainable Development Goals (SDGs)?

The findings of this research significantly contribute to the broader goals of geoheritage conservation and sustainable development, aligning with UNESCO's Sustainable Development Goals (SDGs). By demonstrating the importance of geoeducation in raising awareness and appreciation for geological heritage, this research supports SDG 4 (Quality Education). Through the development and implementation of innovative geoeducational programs, tools, and curricula, local communities, especially students, can gain a deeper understanding of Earth's processes and history, fostering a sense of stewardship and responsibility toward their natural environment. Moreover, the integration of geoeducation into local educational systems ensures that future generations are well-informed and engaged in geoheritage conservation efforts.

The promotion of geoeducation and geotourism directly supports SDG 8 (Decent Work and Economic Growth). By leveraging the unique geological features of the Eastern Aegean islands, geotourism can create sustainable economic opportunities for local communities. This research highlights the potential for geotourism to generate employment, enhance local businesses, and attract investments, contributing to the economic vitality of these regions. Furthermore, the sustainable development of geosites as educational and tourist attractions aligns with SDG 11 (Sustainable Cities and Communities) by promoting sustainable land use, preserving natural heritage, and enhancing the cultural and educational value of these areas.

Geoeducation also contributes to SDG 15 (Life on Land) by promoting the conservation of terrestrial ecosystems and raising awareness about the importance of protecting geological and biological diversity. This research underscores the role of geoeducation in fostering a geo-ethical mindset among locals and tourists, encouraging sustainable practices that protect and preserve geosites. By educating the public about the significance of geological features and the need for their conservation, geoeducation supports broader environmental conservation goals and sustainable land management practices.

Based on the research findings, several recommendations can be made to policymakers, educators, and local communities. Policymakers should prioritize the integration of geoeducation into formal education systems by developing standardized curricula and providing resources and

training for educators. Additionally, policies that support sustainable geotourism development, including eco-friendly infrastructure and visitor management strategies, can enhance the economic and educational value of geosites.

Educators should incorporate geoeducational content into their teaching practices, utilizing innovative tools such as virtual reality and interactive maps to engage students. Developing field-based learning experiences and collaborating with geoscientists can provide students with hands-on learning opportunities that deepen their understanding of geological processes and conservation principles.

Local communities should actively participate in geoeducation and geotourism initiatives, recognizing the economic and cultural benefits these activities can bring. Community-led projects that promote the conservation and sustainable use of geosites can enhance local pride and ownership, ensuring the long-term success of these initiatives. Furthermore, partnerships between community organizations, educational institutions, and tourism operators can create a collaborative approach to geoeducation and geotourism, maximizing their impact and sustainability.

By implementing these recommendations, the Eastern Aegean islands can effectively contribute to geoheritage conservation and sustainable development, aligning with UNESCO's Sustainable Development Goals and ensuring the preservation and appreciation of their unique geological heritage for future generations.

#### 10.1.8. Research Question 8: What is the potential impact of geoeducation on preserving the cultural identity and natural heritage of the Eastern Aegean islands?

Geoeducation has a profound potential impact on preserving the cultural identity and natural heritage of the Eastern Aegean islands. By highlighting the geological and cultural significance of these islands, geoeducation initiatives can foster a deeper understanding and appreciation of their unique landscapes and historical narratives. Educational programs that integrate local geological features with cultural stories can enhance residents' and visitors' connection to the land, creating a sense of pride and stewardship. For instance, incorporating the geological history of volcanic activity in Nisyros into educational materials can enrich the cultural narrative and promote the island's heritage as a key aspect of its identity.

Moreover, geoeducation can support the preservation of natural heritage by educating the public about the importance of geological conservation. Awareness campaigns, school programs, and community workshops can teach sustainable practices that protect geosites from degradation. These initiatives can also involve local communities in conservation efforts, ensuring that preservation is a collaborative effort that respects both geological and cultural heritage. By linking geological features with cultural traditions, such as myths and local history, geoeducation can

create a holistic understanding of the islands' heritage, thereby ensuring its preservation for future generations.

Promoting a geoethical culture among residents and visitors offers significant long-term benefits. By instilling values of respect and responsibility towards the geological environment, geo-ethical education can lead to sustainable behaviors that protect and preserve natural resources. A community that values geoethics is more likely to engage in practices that mitigate environmental damage, such as reducing pollution, supporting conservation efforts, and promoting sustainable tourism. These behaviors not only preserve the natural beauty and ecological integrity of the islands but also ensure that their geological features remain intact for educational and recreational purposes.

Additionally, fostering a geo-ethical culture can enhance the economic sustainability of the islands. Sustainable tourism practices that respect geological monuments can attract environmentally conscious visitors, thereby supporting local economies without compromising the integrity of natural and cultural resources. Educating tourists about the significance of geosites can lead to a more meaningful and respectful engagement with the islands' heritage, promoting long-term visitation and economic stability.

Furthermore, a geoethical culture can strengthen community cohesion and resilience. By working together to preserve their geological and cultural heritage, residents can build a strong sense of identity and solidarity. This collective effort can empower communities to take proactive measures in addressing environmental challenges, ensuring the sustainability of their way of life and the preservation of their unique heritage. Ultimately, the promotion of geo-ethics aligns with broader goals of environmental sustainability and cultural preservation, providing a foundation for the enduring vitality of the Eastern Aegean islands.

## 10.2. Challenges and Future Directions

The scientific community widely acknowledges that Greece, given its status as a tectonically active nation, serves as a natural geological laboratory and museum that has the potential and should be utilized for the purposes of education, information dissemination, and, as a result, raising public awareness. The Greek natural environment, especially the living plants and animals, have been extensively documented, studied, and assessed. In contrast, the geoenvironment, which serves as the basis for the existence of flora and fauna and plays a fundamental role in spatial planning and development policies, has not received comprehensive research and study, and its protection measures are inadequate. This gap is evident in the absence of geoenvironmental education in the Greek schools and universities (**Georgousis et al., 2021**). The critical question is whether sustainable development and a comprehensive understanding of the environment across disciplines can be achieved in the absence of knowledge and integrated management of the geoenvironment.

Based on our review of the literature and our own perspective, we have identified several factors contributing to the insufficient promotion, protection, and integrated management of the geoenvironment in Greece such as:

- i. Greek geoscientists have had a limited role in resource exploration and large-scale development projects since the establishment of the modern Greek state.
- ii. A rapid shift from a survival-focused society to one driven by consumerism and hedonism.
- iii. Viewing the environment as an inexhaustible commodity.
- iv. Delayed adoption of international conventions and European Union environmental legislation.
- v. Underestimating the importance of geological knowledge and heritage.
- vi. A lack of recognition by the Greek state and society regarding the significance of geoscientists and geological knowledge in national development.
- vii. The absence of a geoenvironmental educational and recreational dimension.
- viii. Greece's inability to function as an open, natural geological museum.
- ix. An exploitative and fragmented approach to the geoenvironment.
- x. Difficulty in adapting activities and services related to various geoproducts and resources (e.g., spas, caves, gorges, waterfalls, thermal springs) to changes in Greek society.
- xi. Greek society's struggle to adapt to new realities related to multiculturalism, mobility, the global market, and the economy.

Society often tends to overlook the inherent values within the geoenvironment, which encompasses a broad spectrum of phenomena and processes. It serves as a testament to both human civilization and geological events, making it a destination for scientific exploration and observation, as well as a recreational space for people to connect with nature. The geoenvironment, with its inherent constraints and opportunities, forms the foundation for development planning. Given these factors, the active participation of geoscientists in addressing the challenges posed by Greece's development model, coupled with the growing societal interest in environmental protection (particularly in recent years), necessitates a reassessment of attitudes and policies concerning the geoenvironment.

Considering the aforementioned observations, the objectives for the immediate future should include:

- i. Examining and researching the current institutional framework governing the geoenvironment.
- ii. Documenting the present status of utilized or potentially visitable natural areas, including caves, waterfalls, gorges, thermal springs, and man-made sites like natural history museums and canals.
- iii. Evaluating the developmental potential of geotopes as attractions on local, regional, and national levels.

- iv. Advocating for the preservation of geological heritage and devising strategies for its safeguarding.
- v. Promoting the concept of geotourism.
- vi. Leveraging geological landmarks for educational purposes in primary and secondary schools, especially within environmental education.
- vii. Considering the geoenvironment as an open geological laboratory-museum for higher education.
- viii. Assessing the necessity for new specialized roles like land conservators and tour guides.
- ix. Disseminating geological knowledge, science, and their practical applications in daily life.
- x. Exploring the connections and interplay between the geoenvironment and folklore, literature, mythology, religion, photography, and philately.
- xi. Investigating the relationship between the geoenvironment and leisure activities of individuals.

Assigning a site as a geosite doesn't guarantee its safeguarding and conservation. To achieve effective geoconservation, it's essential to raise awareness of its significance among the public and government authorities. Young individuals can gain knowledge about their local geological heritage through educational initiatives, especially those related to environmental education. Education, particularly in the context of environmental education, can play a pivotal role in the successful preservation of land.

Conserving geological and geomorphological heritage via environmental education can be integrated with approaches focused on the socio-economic advancement of each area. This might include the expansion of alternative tourism forms, like cultural tourism or ecotourism, fostering a more balanced relationship between humans and nature. In this way a better understanding of the conservation of our planet's geological diversity can be achieved (**Catana & Brilha, 2020**)

It is important to reiterate that the existing educational system has diminished the significance of geology within the Greek education framework. There is also a call for the training of innovative and analytical thinkers among scientists who can play a role in addressing energy and natural resource management challenges in Greece, ultimately providing the country with the economic momentum required for enduring development and sustainability.

Another challenge is how the rapid development of technological education can contribute to the promotion of geoeducation and its wider use. Because of the quick evolution of technological education, geoeducation could be promoted through innovative methods and applications like GIS, virtual reality, augmented reality and interactive simulations. These technologies can make learning more engaging and accessible, allowing students and communities to better understand and appreciate geological phenomena, thereby promoting its wider use and integration into various educational and professional fields.

## Chapter 11: Conclusions

The main purpose of this PhD thesis is to advance the field of geoeducation through the development and implementation of GEOAM (Geoeducational Assessment Method). GEOAM serves as a specialized tool designed to assess and enhance the educational potential of geoheritage sites. By evaluating perceptions, attitudes, and understanding among stakeholders such as educators, students, and the community, the thesis aims to gauge the impact of geoeducational programs facilitated by GEOAM. The research investigates how these programs contribute to sustainable development, environmental stewardship, and increased awareness of geological heritage. Through surveys, data analysis, and interpretation of results from Questionnaire B and related assessments, the thesis aims to derive key insights and formulate actionable recommendations. These recommendations are intended to guide the integration of GEOAM into formal educational systems and community engagement initiatives, thereby fostering a deeper public appreciation of geological resources and supporting policies that promote geoeducation and environmental conservation.

GEOAM stands for the GEOeducational Assessment Method. It is an innovative framework designed to enhance geoeducation by assessing and promoting the educational value of geosites. GEOAM aims to integrate geological education into school curricula, fostering a deeper understanding and appreciation of geological heritage among students. The method involves the following key components:

- ✓ Assessment of Geosites: Evaluating geosites based on their educational potential and significance.
- ✓ Educational Resources: Developing user-friendly manuals, guides, and digital resources for teachers.
- ✓ Teacher Training: Organizing workshops, seminars, and mentorship programs to equip educators with the necessary skills and confidence to implement GEOAM.
- ✓ Curriculum Integration: Collaborating with curriculum developers to align GEOAM with existing educational standards and subjects.
- ✓ Pilot Programs: Testing the integration of GEOAM in select schools to identify best practices and areas for improvement.
- ✓ Community Involvement: Engaging local communities through public seminars, media outreach, and collaborative projects to raise awareness and support for geoeducation.

By focusing on these elements, GEOAM seeks to promote sustainable development, geo-ethical awareness, and geotourism, ultimately contributing to the conservation of geological heritage and the preservation of cultural identity within local communities.

Through the research of this doctoral thesis, certain points are identified which need special importance.

Initially, from the statistical survey conducted in the school units, a significant ignorance was identified by both students and teachers about the conceptual framework of landforms, as well as the role and dimension offered by a geological park. Therefore, it would be good to have in a textbook of both primary and secondary education, a separate chapter that develops the relevant concepts that emerge through geoeducation. This will ensure the principles of sustainable development that strengthen the geo-preservation of our planet.

Then, in addition to the systematic recording of the geotopes and their evaluation, the Greek community must take the lead in related activities due to the special geological dynamics it displays. This fact is also confirmed by the existence of the 9 geological parks that have been established relatively recently in the Greek territory. Consequently, there must be collective actions and activities in this direction that will have a more organized character and aim at the rational management of the areas of interest and their global visibility. On this point, the new GEOAM methodology can contribute, since it does not aim at the qualitative characteristics and features of the landforms, but gives importance to the initiatives and applications related to the existence of the landforms. Therefore, the new methodology can be a tool that can help local authorities (stakeholders, policymakers and community) in recording and identifying appropriate actions that will aim to promote landforms. After studying sub-criteria which examine the participation of socio-economic factor at the local level.

In addition, the Greek state, which in recent years has a tendency towards alternative tourism, must rely on and utilize geotourism, which shows a huge potential in the Greek area. To achieve this, however, requires appropriate training both horizontally and vertically. In other words, the local environmental and tourism management bodies, together with the EOT, should proceed with educational actions on issues of geological importance. Thus, in the future, there will be the right foundations at a collective level for the development and proper promotion of the management of areas of geological importance.

Also, the school of guides would do well to include courses of a geological nature in the curriculum, so that in the future there would be a specialty of geoguides, which would be certified by the appropriate body. Such an initiative will be the cornerstone of the Greek state in terms of the proper promotion of the geological areas. This will also be a significant advantage with economic components for Greek society. Since there will be an influx of tourists and educational institutions interested in geological issues.

In addition, the new methodology covers a wide interdisciplinary spectrum beyond the geological value. Such as cultural, economic, social and geoethical value, reflected by community efforts. More specifically, the methodology is a pioneer since it examines hypocrites that indulge in climate change and the influence of human factors (such as gas emissions or the use of renewable sources) in terms of the state of the landform. For this reason, it can be applied not only

by a geologist but also by educators related to environmental education. In fact, environmental education centers could apply it in order to promote the geo-heritage value of each region. Thus, a geoethical culture will be cultivated in the educational community and therefore future generations will operate with increased environmental empathy. Furthermore, it is worth mentioning that the creation and implementation of geo-environmental programs by specialized staff in school units is of utmost importance. Because there is a significant difference between environmental and geo-environmental programs in terms of their subject matter. For this reason, it would perhaps be good to set up a public body that will promote and offer geo-educational experiences to everyone interested. In this way, the highlighting of geoheritage value, the protection of areas of intense geological interest and finally the development of a geoethical culture that will ensure sustainable development will be achieved.

Additionally, promoting geoeducation and geotourism aligns with several of UNESCO's Sustainable Development Goals (SDGs), particularly those related to quality education (Goal 4), decent work and economic growth (Goal 8), sustainable cities and communities (Goal 11), and life on land (Goal 15). By raising geo-ethical awareness and fostering a culture of sustainability, these initiatives can contribute significantly to the conservation of geoheritage and the preservation of cultural identity.

However, several challenges must be addressed to achieve these goals. These include overcoming the lack of awareness and understanding of geoheritage, addressing the limitations of current educational resources, and ensuring community involvement and ownership of geoeducational programs. New measures such as enhanced teacher training, increased funding for educational resources, and the development of community-based geoeducation initiatives can help overcome these challenges.

In conclusion, the integration of geoeducation and geotourism offers a viable pathway for promoting sustainable development and conserving geoheritage on the Eastern Aegean islands. By addressing existing challenges and leveraging available opportunities, these initiatives can foster a deeper understanding and appreciation of geological heritage, contributing to the broader goals of environmental sustainability and cultural preservation.

Through meticulous monitoring and adaptive feedback mechanisms, GEOAM's implementation can be continuously refined and improved. Establishing clear benchmarks and success indicators, combined with a robust ongoing assessment strategy, ensures systematic tracking of progress and impact. Effective feedback mechanisms make the program responsive to the needs of teachers, students, and parents. Gradual expansion, informed by pilot programs, will facilitate broader adoption, enhancing geoeducation in Kalymnos, Nisyros, and Samos. This approach promotes a deeper understanding of geological heritage, contributing to sustainable development and geo-ethical awareness in these regions.

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# Appendices

## Appendix A: GEOAM Assessment Form

Evaluation form of GEOAM	Scoring system (1-2-3-4-5)	Overall score
<b>1. SMVE Site management and visitor experience</b>		
1.1 Site accessibility		<b>SMVE * 0.10</b>
1.2 Signage and interpretation		
1.3 Staff knowledge and visitor interaction		
1.4 Visitor facilities		
1.5 Site maintenance		
1.6 Safety and security		
Average for SMVE		
<b>2. NRM Natural resource management</b>		
2.1 The conservation of biodiversity		<b>NRM * 0.10</b>
2.2 The preservation of ecosystems		
2.3 The sustainable use of natural resources		
2.4 Pollution prevention and control		
2.5 Climate change mitigation and adaptation		
Average for NRM		
<b>3. EEI Environmental education and interpretation</b>		
3.1 The presence of interpretive signage or exhibits		<b>EEI * 0.30</b>
3.2 The availability of trained interpretive staff or volunteers		
3.3 The integration of environmental education and interpretation		
3.4 The inclusion of interactive and hands-on activities		
3.5 The incorporation of environmentally friendly practices		
Average for EEI		
<b>4. CHS Cultural and historical significance</b>		
4.1 Historical significance		<b>CHS * 0.10</b>
4.2 Cultural significance		
4.3 Interpretation and education		
4.4 Cultural diversity and inclusivity		
Average for CHS		
<b>5. CIE Community involvement and engagement</b>		
5.1 Stakeholder participation		<b>CIE * 0.05</b>
5.2 Cultural sensitivity		
5.3 Community benefits		
5.4 Outreach and communication		
Average for CIE		
<b>6. GE Geoethics</b>		
6.1 Environmental impact		<b>GE * 0.20</b>
6.2 Cultural heritage		
6.3 Social responsibility		
6.4 Transparency and accountability		
6.5 Professional conduct		
Average for GE		
<b>7. EV Economic viability</b>		
7.1 Tourist revenue potential		<b>EV * 0.05</b>
7.2 Local economic impact		
7.3 Economic benefit sustainability		
7.4 Management cost-effectiveness		
7.5 Innovative economic models		
Average for EV		

<b>8. SD Sustainable development</b>		
8.1 Resource efficiency		<b>SD * 0.10</b>
8.2 Waste management		
8.3 Biodiversity conservation		
8.4 Social and economic consequences		
8.5 Climate change adaptation		
8.6 Cultural heritage preservation		
	Average for SD	
	<b>Overall score</b>	

## Appendix B: Sample Lesson Plan: Exploring Local Geosites Using GEOAM

Students Age: 13 – 14 years old

Subject: Geography - Geology

Duration: 90 minutes

### *Objective:*

- Students will apply GEOAM methodologies to assess the geoeducational value of a local geosite.
- Students will understand the geological, cultural, and environmental significance of the geosite.

### *Materials Needed:*

- GEOAM assessment criteria handouts
- Field notebooks or digital devices for data collection
- Map of the geosite and surrounding area
- Photos or videos of the geosite (optional)
- Computers/tablets for research (optional)

### *Preparation:*

- Prior to the lesson, identify a local geosite accessible for a field trip or virtual exploration.
- Prepare GEOAM assessment criteria handouts and ensure students have access to necessary materials.
- Arrange transportation or ensure students have instructions for accessing the geosite virtually if applicable.

### *Procedure:*

#### 1. Introduction (10 minutes)

- Begin by discussing the importance of geoeducation and how understanding local geosites contributes to broader environmental awareness.
- Introduce the GEOAM assessment framework and explain its relevance to the lesson.

#### 2. Background Information (15 minutes)

- Provide students with background information about the selected geosite. Discuss its geological formation, cultural significance, and environmental impact.

- Show photos or videos of the geosite to give students a visual understanding.

### 3. GEOAM Assessment (25 minutes)

- Distribute GEOAM assessment criteria handouts and explain each criterion briefly.
- Divide students into small groups and assign each group a specific aspect of GEOAM to focus on (e.g., geological features, educational potential, accessibility).
- Instruct students to assess the geosite based on these criteria, either through onsite observations or virtual exploration.

### 4. Data Collection (20 minutes)

- Students collect data using field notebooks or digital devices. They record observations, take measurements (if applicable), and document their findings.
- Encourage students to take photos or videos to support their assessments.

### 5. Group Discussion (15 minutes)

- Reconvene as a whole class or in small groups to discuss findings.
- Each group presents their assessment and explains how the geosite meets or doesn't meet GEOAM criteria.
- Facilitate a discussion on the importance of preserving and educating about local geosites.

### 6. Conclusion and Reflection (5 minutes)

- Conclude the lesson by summarizing key points about the geosite and its GEOAM assessment.
- Ask students to reflect on what they learned and how it connects to broader environmental and geological concepts.

#### *Homework/Extension:*

- Assign students to write a reflection on their GEOAM assessment experience. Prompt them to consider how their local geosite contributes to their understanding of geoeducation.

## Appendix C: Benchmarks and Success Indicators for GEOAM Implementation

### 1. Training and Professional Development Benchmarks

- i. Schools Trained: Number of schools participating in GEOAM training.
- ii. Teachers Trained: Number of teachers completing GEOAM training workshops.
- iii. Mentorship Pairs: Number of mentor-mentee pairs active in the mentorship program.

### 2. Student Engagement Indicators

- i. GEOAM Activities Participation: Number of students involved in GEOAM-related classroom activities and projects.
- ii. Student Projects: Number of student-led projects assessing local geosites using GEOAM methods.

### 3. Educational Impact Benchmarks

- i. Geological Knowledge Improvement: Improvements in students' geological knowledge based on pre- and post-tests.
- ii. Classroom Integration: Frequency and quality of GEOAM activities in geography, geology, and environmental science lessons.
- iii. Field Trips: Number of educational field trips to local geosites.

### 4. Community and Extracurricular Involvement Indicators

- i. Public Seminars: Number of public seminars and workshops on GEOAM and geoeducation.
- ii. Community Projects: Number of community projects like geosite tours and educational fairs.
- iii. Media Coverage: Extent of media coverage about GEOAM activities.

## 5. Program Evaluation and Feedback Benchmarks

- i. Feedback Collection: Amount of feedback from teachers, students, and parents through surveys and focus groups.
- ii. Regular Assessments: Frequency of evaluations to measure GEOAM's effectiveness, including classroom observations.
- iii. Program Improvements: Number of changes and improvements made based on feedback.

## 6. Resource Allocation and Utilization Indicators

- i. Funding Secured: Amount and sources of funding obtained for GEOAM.
- ii. Resource Availability: Distribution and availability of GEOAM manuals, guides, and digital resources.
- iii. Online Platform Usage: Engagement levels on the GEOAM online platform, including use of tutorials and discussion forums.

## Appendix D: Questionnaire A (pre-test)

### QA01. Educational status:

- 01.1 I am pupil in a junior high school
- 01.2 I am teacher in a junior high school

### QA02. Gender:

- 02.1 Female
- 02.2 Male

### QA03. Am I aware of the geological situation of the area in which I live?

- Yes
- No

### QA04. I have visited the areas with strong geological features in my place of residence:

- Yes
- No

### QA05. I know basic information about the wider geological feature of my area because I studied a book of:

- 05.1 Geology – Geography
- 05.2 History
- 05.3 Wider bibliographic sources
- 05.4 I do not know

### QA06. The course of Geology - Geography is taught by:

- 06.1 Geologist
- 06.2 Physicist
- 06.3 Chemist
- 06.4 Biologist
- 06.5 Other specialty: \_\_\_\_\_

### QA07. Participation in programs:

- 07.1 I have participated in a school geoenvironmental educational program
- 07.2 I have participated in other types of educational programs
- 07.3 I have participated in an extracurricular environmental program

07.4 I have not participated in any environmental or educational program

**QA08.** I am aware of the geological evolution of Greece:

Yes No

**QA09.** I am aware of Greek volcanic arc and its main areas:

Yes No

**QA10.** Why does Greece have strong seismicity?

10.1 Because of its volcanoes

10.2 Due to climatic conditions

10.3 Due to the point of convergence of lithospheric plates

10.4 Because of its rocks

**QA11.** I am aware of the term geosite:

Yes No

**QA12.** I am aware of the term geological park and its meaning:

Yes No

**QA13.** I am aware of the term geoheritage and its meaning:

Yes No

**QA14.** I am aware of the term geodiversity:

Yes No

**QA15.** I am aware of the term geoconservation:

Yes No

**QA16.** I know if Greece has geological parks:

Yes No

**QA17.** I am aware of the term sustainable development and its benefits:

Yes No

**QA18.** Have you ever heard of geoeducation?

Yes No

If so, please state: \_\_\_\_\_

**QA19.** I know the role and importance of geoeducation:

Yes No

**QA20.** I am aware of various geoeducational activities:

Yes No

If so, please list some: \_\_\_\_\_

**QA21.** I am aware of the term geoethics and its meaning:

Yes No

**QA22.** I believe that geoeducation can contribute positively to a society:

Yes No

If so, please state how: \_\_\_\_\_

**QA23.** I am engaged in geoeducational activities:

Yes No

**QA24.** I know how many geological parks Greece has and where they are located:

Yes No

**QA25.** I think that geoeducation is also connected with cultural or archaeological values:

Yes No

## Appendix E: Exercises of geoeucational program

### Exercise 1

<b>Instructions: Indicate whether each statement is correct or incorrect by marking "T" for True or "F" for False.</b>		
	True	False
1. Most caves are naturally formed, not by anthropogenic causes	<input type="checkbox"/>	<input type="checkbox"/>
2. The concepts cave and hollow are different	<input type="checkbox"/>	<input type="checkbox"/>
3. Stalactites are drops of water	<input type="checkbox"/>	<input type="checkbox"/>
4. Stalagmites are formed at the base of a cave	<input type="checkbox"/>	<input type="checkbox"/>
5. Limestone as a rock has quite a bit of porosity	<input type="checkbox"/>	<input type="checkbox"/>
6. In a cave there are only abiotic factors	<input type="checkbox"/>	<input type="checkbox"/>
7. The climbing field is created in a rift area mainly	<input type="checkbox"/>	<input type="checkbox"/>
8. The main types of faults are divided into three categories	<input type="checkbox"/>	<input type="checkbox"/>
9. Geoconservation relates to a set of activities related to the conservation and rational management of areas of intense geological importance	<input type="checkbox"/>	<input type="checkbox"/>
10. Geoethics is concerned with the interaction of the environment and human activities on a basis of respect for geological processes that have evolved over time.	<input type="checkbox"/>	<input type="checkbox"/>
11. The geosite is of no geological or historical interest	<input type="checkbox"/>	<input type="checkbox"/>
12. Geoeducation is linked to geotourism	<input type="checkbox"/>	<input type="checkbox"/>
13. Geoeducation is linked to sustainable development	<input type="checkbox"/>	<input type="checkbox"/>
14. The cave can be created in a year	<input type="checkbox"/>	<input type="checkbox"/>
15. Cave speleothemes are fossils	<input type="checkbox"/>	<input type="checkbox"/>

### Exercise 2

<b>Choose the correct answer to the following questions</b>			
1. Caves are created by	a. humans	b. natural geological processes	c. both a and b
2. Hollows can only be entered by	a. humans	b. small animals	c. no organisms
3. Caves contains	a. biotic factors	b. abiotic factors	c. both biotic and abiotic factors
4. Stalactites are found	a. on the ceiling of a cave	b. at the floor of a cave	c. both a and b
5. Stalagmites are found	a. on the ceiling of a cave	b. at the floor of a cave	c. both a and b
6. A cave is created mainly within			

	a. limestone rocks	b. granitic rocks	c. igneous rocks
7. Limestone is	a. a metamorphic rock	b. a sedimentary rock	c. an igneous rock
8. The life cycle of a cave is divided into	a. two stages	b. three stages	c. four stages
9. A cave depending on temperature conditions can be divided into	a. four zones	b. three zones	c. two zones
10. A geoeducational activity can be organized by	a. an educator of any direction	b. geologist	c. no one


### Exercise 3

Find the hidden words related to geological concepts

#### Explore the geoheritage of Kalymnos

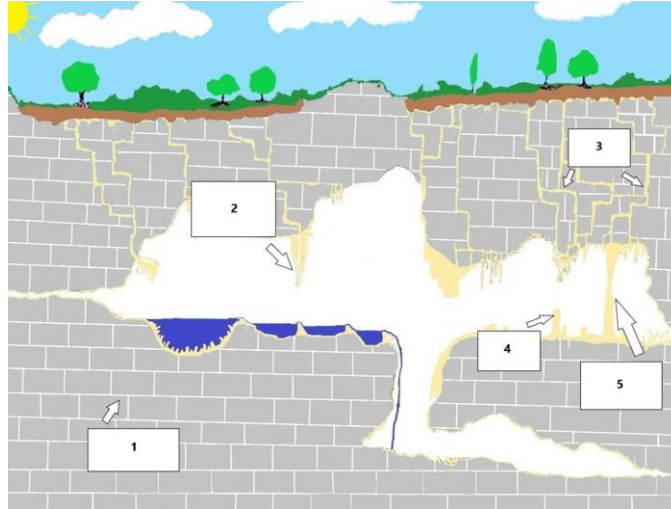
O	L	C	I	T	T	C	T	F	P	I	E	A	E
C	H	I	T	E	S	U	C	T	S	T	S	S	A
S	A	C	R	M	B	I	O	T	I	C	P	T	R
C	L	A	P	A	C	W	A	T	E	R	E	A	L
O	I	L	E	O	C	T	R	T	O	S	L	L	U
L	M	C	B	S	T	C	C	T	M	T	E	A	T
U	E	I	S	E	R	B	L	E	I	A	O	G	G
M	S	L	U	R	T	N	A	S	E	L	T	M	A
N	T	I	B	O	O	A	N	T	M	A	H	I	G
N	O	T	I	S	A	T	A	I	S	C	E	T	E
C	N	E	O	I	S	M	C	O	L	T	M	E	V
T	E	O	L	O	E	E	L	A	L	I	L	E	A
I	U	M	M	N	U	E	R	F	F	T	G	O	C
C	L	R	A	A	T	A	M	U	I	E	E	L	I

LIMESTONE  
WATER  
STALACTITE  
FACTORS  
SPELEOTHEM  
CAVE  
CALCILITE  
COLUMN  
EROSION  
BAT  
STALAGMITE  
BIOTIC



### Exercise 4

Fill in the blanks with the appropriate geological terms



### Exercise 5

Please indicate your level of agreement with the following statements					
1. Strongly disagree 2. Disagree 3. Neither disagree nor agree 4. Agree 5. Strongly agree					
	1	2	3	4	5
1. The geoeducational program helped in understanding geological concepts and processes.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. The geoeducational program increased awareness of the protection and conservation of the geoenvironment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. The geoeducational program strengthened the exploration of areas with significant geological content and fostered a geoethical culture.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. The geoeducational program promoted the principles of sustainable development.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. I would recommend this geoeducational program to others.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Geoeducation can be effectively developed using ICT.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. This geoeducational program has a constructive effect on students' attitude.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. This geoeducational program contributes to the creation of a culture of citizens with a higher environmental consciousness.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Do you think that a geoeducational program contributes to the creation of a culture of citizens with a higher environmental attitude?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Do you think that during the geoeducational program you had the opportunity to develop skills such as: communication, creativity, collaboration and critical thinking?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Appendix F: Questionnaire B (post-test)

### QB01. Educational status

- 01.1 I am pupil in a junior high school
- 01.2 I am teacher in a junior high school

### QB02. Gender

- 02.1 Female
- 02.2 Male

### QB03. How do you think geoeducation will be developed and spread?

- 03.1 Through intramural activities and similar geoeducational programs
- 03.2 Through a document that will contain its meaning and dimensions
- 03.3 Through extracurricular geoenvironmental activities
- 03.4 Through initiatives of the municipality or the local community

### QB04. You consider the term geoeducation to be mainly related:

- 04.1 To the transmission of knowledge about geological features and processes
- 04.2 To the protection of the environment
- 04.3 To the sensitivity of citizens for the rational utilization of an area with strong geological characteristics
- 04.4 To the development of activities that will bring an influx of tourists to an area

### QB05. You consider the term geoheritage is related to:

- 05.1 The recording and mapping of areas of intense geological interest
- 05.2 The protection of areas of high environmental value
- 05.3 The management of areas of high geological value
- 05.4 The sustainable development

### QB06. You consider the term geoconservation is associated with:

- 06.1 A set of actions that contribute to the conservation and rational management of areas of geological interest
- 06.2 The protection of the environment
- 06.3 The principles of sustainable development

06.4 The management and development of geotourism areas

**QB07.** You consider the term geoethics is related to:

07.1 The interaction of environment and human activity

07.2 The rational management of the ecosystem

07.3 The exploitation of areas of high geological interest

07.4 The development of sustainability

**QB08.** You consider the term geosite is associated with:

08.1 A site of strong geological and geomorphological interest

08.2 A site where special geological rocks are found

08.3 A place where extremely rare fossils are found

08.4 An area where rare species of flora and fauna are found

**QB09.** You consider the term geopark is connected to:

09.1 An area containing a set of several points and sites of high geological interest

09.2 A site that must be environmentally protected

09.3 An area showing geotourism development

09.4 An area where several biotic and abiotic factors are found

**QB10.** In your opinion, what is the most important sector that geoeducation should develop (choose more than one answer):

10.1 Geoscientific knowledge

10.2 Awareness regarding natural disasters

10.3 Rational use of mineral wealth

10.4 Awareness of sustainable development and its applications

10.5 Awareness of geoheritage

10.6 Awareness of geoconservation and environmental protection

10.7 Awareness of geoethics and its beneficial dimensions

**QB11.** Geotourism is a form of tourism:

11.1 With the main object of geoeducational activities and visiting areas with high geological value

- 11.2 With alternative activities (alternative tourism)
- 11.3 For the development of tourism infrastructure
- 11.4 Series of activities for the protection of the environment

Please indicate (√) the extent to which you agree with the following suggestions.

**1: Strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, 5: Strongly agree**

	1	2	3	4	5
<b>QB12.</b> Do you think that the educational system contributes to the promotion of geoeducation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB13.</b> Do you think there are geoeducational programs that will promote and highlight geoheritage at a national level?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB14.</b> Would you like to participate in geoeducational activities or programs?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB15.</b> Do you think that geoeducation will contribute to sustainable development?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB16.</b> Would you be interested in learning more about geoeducation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB17.</b> Do you consider that geoeducation beyond geological values, transmits additional historical, archaeological values etc?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB18.</b> Do you think that geoeducation contributes to the economic development of an area?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB19.</b> Do you think that geoeducation contributes to the citizens' awareness for the preservation and protection of the environment?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB20.</b> Do you think that geoeducational activities can change the standard of living of the citizens of a local community?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB21.</b> Do you think that geoeducational activities will contribute to geotourism development of an area?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB22.</b> Do you think that awareness of geoheritage value will help in the preservation and protection of the environment?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB23.</b> Do you think that awareness of geoheritage will contribute to the transmission of the principles of sustainable development?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB24.</b> Do you think that the transmission of the geoheritage value will contribute to the awareness of the citizens for the protection and utilization of the geological areas that show strong interest?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>QB25.</b> Do you think that geoeducation promotes various recreational activities?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>