Georoutes as a Basis for Territorial Development of the Pacific Coast of South America: a Case Study

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ORIGINAL ARTICLE

Georoutes as a Basis for Territorial Development of the Pacific Coast of South America: a Case Study

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Abstract
Thematic travel itineraries (e.g. architectural, archaeological, geological routes) can be instrumental in developing tourism in a given area. Travellers are expected to follow the itineraries to visit natural, cultural, historical, or religious places. This work aims to propose three geological routes (georoutes) in the Santa Elena province as a base for geotourism development. The methodology includes (i) the compilation of a geosite inventory that covers geosites and sites of industrial interest; (ii) the proposal of georoutes (GR-I, GR-II, and GR-III); (iii) the evaluation of the proposed routes through the Geotouristic Route Assessment (GtRAM) method and the study of reception capacity of the territory; (iv) the description of strategies for local geotourism development based on a SWOT analysis. The GtRAM method yields "average" values for all of the proposed routes (2.16/5, 2.68/5, and 2.74/5 for routes GR-I, GR-II, and GR-III, respectively). According to the reception capacity study, 85.2% of the geosites are in intrinsic use and are compatible with the proposed activities; therefore, the environmental impact of the georoutes is expected to be low. The SWOT analysis revealed that geotourism development is possible if based on strategic planning. In conclusion, the proposed georoutes will complement local economic activities, and thus contribute to local development.

Keywords Geosites · Geoheritage · Assessment · Routes · Geotourism · Santa Elena Geopark Project

Introduction and Objective

Overview

Natural diversity is a general concept that integrates *geodiversity* and biodiversity (Brilha 2016). According to Gray (2004) and Migoń (2021), the term geodiversity expresses the natural variety of geological (rocks, minerals, fossils), geomorphological, hydrological, and soil characteristics. These geological traits are the natural physical substratum of a territory where organic and anthropogenic activity occurs (Nieto 2001).

Unique elements of geodiversity are protected in the context of *geological heritage* (Brilha 2018). This concept arises from the need to conserve geological features of outstanding value (Carcavilla et al. 2007). According to Brilha (2005) and Carcavilla et al. (2008), geological heritage can be defined as a set of geological elements with outstanding scientific, cultural, and educational values. On the other hand, industrial heritage consists of objects, buildings, and systems related to past industrial activities (Institute of the Cultural Heritage of Spain (IPCE) 2016).

Geosites are natural sites with scientific, cultural, and tourism values (Brilha 2016) that are part of the geological heritage of a territory (Fuertes-Gutiérrez and Fernández-Martínez 2012; Palacio Prieto 2013). Geosite assessment can be approached through qualitative and quantitative methods. These methods help identify and assess the geosite's geological interest regarding scientific, educational, tourism, use and protection, functional, cultural, ecological, and

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economic values. Some examples of assessment methods are (i) the IELIG method (acronym in Spanish "Inventario Español de Lugares de Interés Geológico") (García-Cortés and Carcavilla 2013), which is a systematic evaluation process considering variables, such as intrinsic character, didactic potential, and recreational tourism; (ii) the Brilha method (Brilha 2016), which provides a quantitative assessment of geosites with a focus on geoconservation; (iii) the Geosite Assessment Model (GAM) method (Vujičić et al. 2011), a preliminary model for the assessment of scientific/educational, aesthetic/scenic, protection, functional use, and tourism variables; (iv) the Pereira et al. (2007) method, which assesses quantitatively the scientific value, use value, protection value, and additional values of geomorphological heritage.

Geoparks represent the geological heritage of a territory; they englobe natural and cultural values and aim to enhance awareness and understanding of the resources used by society (UNESCO 2020). Some geoparks are recognised globally by the United Nations Educational, Scientific and Cultural Organization (UNESCO), such as the Styrian Eisenwurzen Geopark (Austria), the Tumbler Ridge Geopark (Canada), the Vulkaneifel Geopark (Germany), the Arouca Geopark (Portugal), and the Sierra Norte de Sevilla Geopark (Spain) (UNESCO 2021).

In recent years, the number of geoparks has increased considerably, reaching 169 by 2021 (UNESCO 2021). The growing interest in geopark creation produced numerous new studies on geosite characterisation (Eder 1999; Reynard and Brilha 2017).

One of the common strategies to facilitate tourism within geoparks is the creation of "*geological routes*" or *georoutes* that connect geosites of unique geological interest and are suitable for education, research, and tourism activities (Meléndez et al. 2012; Albani et al. 2020). In the definition of Carrión-Mero et al. (2021b), "the geological routes connect geosites in a sequential and orderly manner to represent a given sector's geodiversity. These tours are self-guided and designed to know the natural space's characteristics through a route where stops are established. Materials such as information panels, explanatory brochures, and a guide allow the correct interpretation of the places". According to Tabera et al. (2017), georoutes are outreach tools that share information, promote conservation, and display geosites through the interaction between "visitors and earth phenomena". Some routes of international interest are the geotrails in the Yanhuitlán Geopark (Mexico) (Palacio Prieto et al. 2019), the "Trans-Pyrenean Geological Route" (France) (Venzal 2014), the "Palaeontological heritage of mammoths through a cross-country thematic route" (Serbia) (Antić et al. 2021), and Demnate and High-Tessaout valley (Morocco) (Bouzekraoui et al. 2018). The Mineral Routes and Sustainability Project (RUMYS, acronym in Spanish) promotes routes that disseminate the geological mining heritage and other, for example architectural, archaeological, and cultural sites in Iberoamerica (Mata-Perelló et al. 2018). Some examples are the "Ruta del Oro" (Colombia) (Delgado Martínez and Pantoja Timarán 2015), the "Ruta de las Piritas" (Spain) (González-Martínez and Carvajal Gómez 2013), the "Estrada Real" (Brazil) (Pires 2017), and the "Ruta del Oro" (Ecuador) (Carrión Mero et al. 2018). Therefore, geoparks and georoutes are promotional tools of *geotourism* providing new entrepreneurial and business opportunities to the inhabitants of a territory (Carcavilla et al. 2015; Simón-Porcar et al. 2020). UNESCO-recognised geoparks and geopark projects use Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis to identify strategic plans and geotourism development within a sustainability framework, e.g. Yimengshan Geopark (Cai et al. 2019), Geopark Merangin Jambi in Indonesia (Wibowo et al. 2019), "Litoral del Biobío" Mining Geopark project in Chile (Ferraro et al. 2020), and proposed geopark Uzundere in Turkey (Özgeriş and Karahan 2021).

Geotourism was defined in the mid-1990s as "geological" tourism by geologists, and as "geographic" tourism by the National Geographic Society (Hose 1996). According to Arouca Declaration (2011) and Farsani et al. (2011), geotourism is a form of tourism to natural areas that sustains and enhances territory quality, focusing on geology, environment, culture, aesthetic values, heritage, and well-being of residents. The latter definition directly links the term geodiversity to the creation of UNESCO Geoparks. This definition conceives geotourism as Earth tourism, in which geology is part of the Earth's natural environment. Geotourism can foster geodiversity conservation and generate scientific knowledge (Dowling 2013; Newsome and Dowling 2018; Carrión Mero et al. 2018); however, if not managed correctly and effectively, it can present a threat to the resources of geological heritage (Newsome et al. 2012).

In Ecuador, there are legal and regulatory measures to protect cultural and natural heritage. An example is the Constitution of the Republic of Ecuador (Asamblea Nacional del Ecuador 2008): Article 83 refers to the protection of Ecuador's territorial integrity and its natural resources, the respect for nature, the preservation of the natural environment, the conservation of the country's cultural and natural heritage. and the rational and sustainable use of its natural resources. Article 389 provides that the state shall protect people, communities, and nature against negative effects caused by anthropogenic actions. Articles 400 and 404 are concerned with nature protection, natural resources, and natural heritage, including physical, biological, and geological formations.

The "Draft Organic Law on UNESCO's Global Geoparks in Ecuador" (Asamblea Nacional del Ecuador 2019) provides a legislative framework for the fulfilment of international treaties with the United Nations (UN) and the UNESCO's Earth Sciences and Geoparks programme. Furthermore, the National System of Protected Areas (SNAP, acronym in Spanish) (Ministerio del Ambiente y Agua 2015) manages the conservation and use of 56 protected areas in Ecuador.

The Ecuadorian Geopark Committee (CEG, acronym in Spanish) (Sánchez-Cortez 2019) is an initiative to implement sustainable strategies (geoparks, routes, and protection figures) in places of heritage value. As a result of their activity, in February 2019, the Imbabura Geopark was officially declared a UNESCO's Global Geopark, the first geopark recognised in Ecuador and the seventh geopark in South America (UNESCO 2019; Berrezueta et al. 2021). Other initiatives, such as the Tungurahua Volcano Geopark Project (Aguilar Soria et al. 2020), the Napo Sumaco Geopark project (Sánchez-Cortez 2019), the Santa Elena Geopark project (Herrera et al. 2018), the Puyango Petrified Forest (Jaramillo et al. 2017), the Jama Pedernales project (Andrade et al. 2020), and the "Ruta del Oro" (Gold Route) project (Carrión Mero et al. 2018) have also been presented to the UNESCO.

The Santa Elena Province is in the western part of the coastal region, in the southwest of Ecuador (Fig. 1b). It has an extension of 3691 km^2 (González Artieda et al. 2012), an altitudinal range from 0 to 800 m.a.s.l., and an average temperature of 27 °C. The climate is tropical with two annual seasons: a dry period (winter) between June and November and a wet or rainy period with high temperatures (summer) between December and May. The province has economic activities; in particular, tourism has been flourishing in areas of geomorphological, biological, cultural, paleontological, and archaeological character (Marcos 2003; García Alarcón et al. 2020; Herrera-Franco et al. 2021). Tourism has allowed the villages to develop socioeconomically at the local level. The main cities of the region (Fig. 1c) are Santa Elena, the administrative capital, La Libertad, and Salinas; and some of the rural communities (Fig. 1c) are Ballenita, Ancón, Anconcito, Chanduy, Atahualpa, Zapotal, San Pablo, Ayangue, Valdivia, Dos Mangas, San Vicente, Manglaralto, Montañita, and Olón (GAD Santa Elena 2015).

The province has a flat and slightly undulating morphology and a low to moderate hilly relief (100 to 200 m) developed over fine detrital fill and cliffs composed of clays, silts, and sands (González Artieda et al. 2012). Faults parallel to the coastline formed the coastal geomorphology and resulted in coastal cliffs of marine rocks and marine terraces of various levels (Winckell 1982). There are settlements in various geological and hydrogeological settings, such as rivers, waterfalls, cliffs, beaches, aquifers, mountains, and hills. The province has oil reserves in the Santo Tomas, Socorro, Passage Bed, Clay Pebble, and Seca formations (Villacís Maita 2018).

The province borders with the Progreso and Zapotal Basins to the east; the Chongón Colonche Mountain Range (Cayo Fm.) to the north; the littoral edge with the alluvial plain to the west; and the cliffs and reliefs of the Ancón Group, Azúcar Group, and Tablazo Formation to the south (Fig. 2). The geomechanical character of the area is complex and features fold structures and reverse fault series, mainly in the central and southern parts of the province (Chunga 2013).

Objective and Scope

The main objective of this contribution was to propose three georoutes within the framework of the geopark project in Santa Elena province (Ecuador), and to provide an overall evaluation of these itineraries as a basis for promoting territorial development in the region.

Available information on geosites was compiled and analysed with a special focus on those geosite and georoute assessment methods that consider reception capacity. The purpose of this study was to lay the foundations for more detailed future work.

Materials and Methods

The study was developed in four phases (Fig. 3): (i) inventory of geosites (including sites of geomorphological, structural, stratigraphic, hydrogeological, and palaeontological character) and sites of industrial heritage interest; (ii) proposal of itineraries combining geosites and sites of industrial heritage interest; (iii) assessment of the proposed routes through the GtRAM method (Herrera-Franco et al. 2020b; Carrión-Mero et al. 2021b) and general study of their reception capacity in the territory (Gómez Orea 2008); (iv) definition of strategies based on a SWOT analysis (Dyson 2004) to evaluate the routes and their influence on local geotourism development.

Phase I: Inventory of Geosites

The first phase consisted of the compilation and analysis of initiatives addressing geosite inventory, assessment, and cataloguing in the Santa Elena province. Used search terms were "geosites", "Punto de Interés Geoturístico" ("Point of Geotourism Interest", PIG, acronym in Spanish), "assessment", "IELIG method", "GREGSIC method", "Barba method", "Santa Elena", and "Ecuador". The search produced two journal articles, one academic thesis, one conference paper, and one research project, all of them indexed in databases and search platforms (e.g. Scopus or Google Scholar). Collected data included location, characteristics, and type of the geosites, data on existing infrastructures, and of the inhabited areas (population, service areas, etc.). The compiled publications assessed

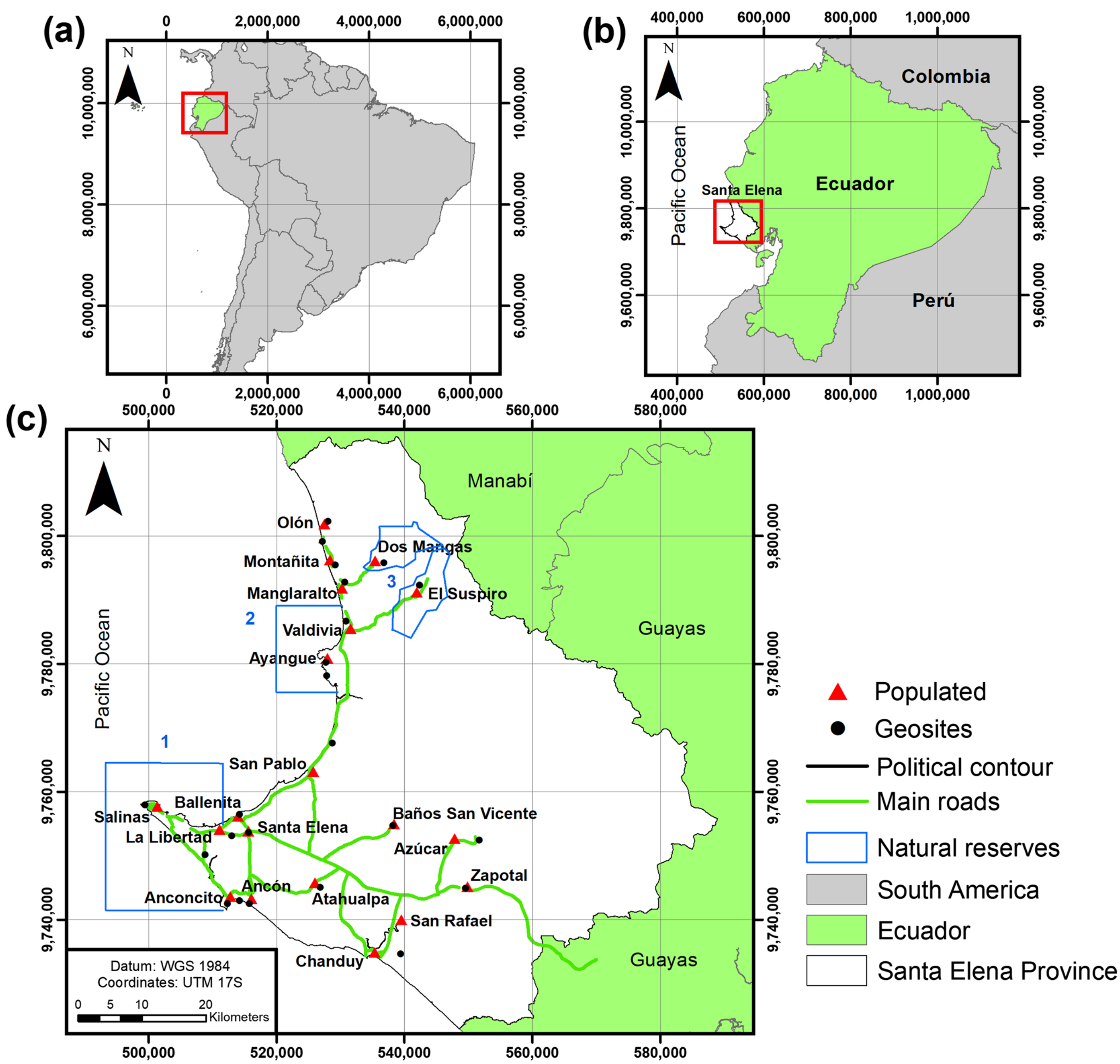


Fig. 1 (**a**) The geography of Ecuador; (**b**) Santa Elena province, Ecuador; (**c**) map of Santa Elena province indicating municipalities, geosites, and natural reserves (1. "El Pelado" marine reserve; 2. "Reserva de Producción de Fauna Marino Costera Puntilla de Santa Elena"; 3. "Comunal Loma Alta and Comuna Dos Mangas" ecological reserve) (Ministerio del Ambiente 2015; Astudillo-Sánchez et al. 2020). Based on Gobierno Autónomo Descentralizado Municipal de Santa Elena 2014; Secretaría Nacional de Planificación 2014

geosites within the Peninsula Santa Elena Geopark project's geosites. The comparative analysis of these assessments provided an input for the selection of geosites in the second phase of this work.

Phase II: Proposal of Itineraries

In the second phase, itineraries or georoutes (GR) were proposed based on the opinion of an expert committee (i.e. three geological engineers with experience in geotourism and geoscience). The process consisted of (i) selecting geosites based on the parameters of representativeness, accessibility, and connection with other geosites; (ii) planning routes that link geosites within a reasonable scope (approximate distances of 68 to 100 km and tour duration of 1 to 3 days by vehicle); (iii) implementing routes in an information system (GIS, ArcGIS) to create maps (e.g. virtual navigation maps) and conduct analysis (e.g. reception capacity analysis); and (iv) describing georoutes highlighting particularities, route distance, accesses, nearby services, municipalities, or other sites (cultural, archaeological, gastronomic).

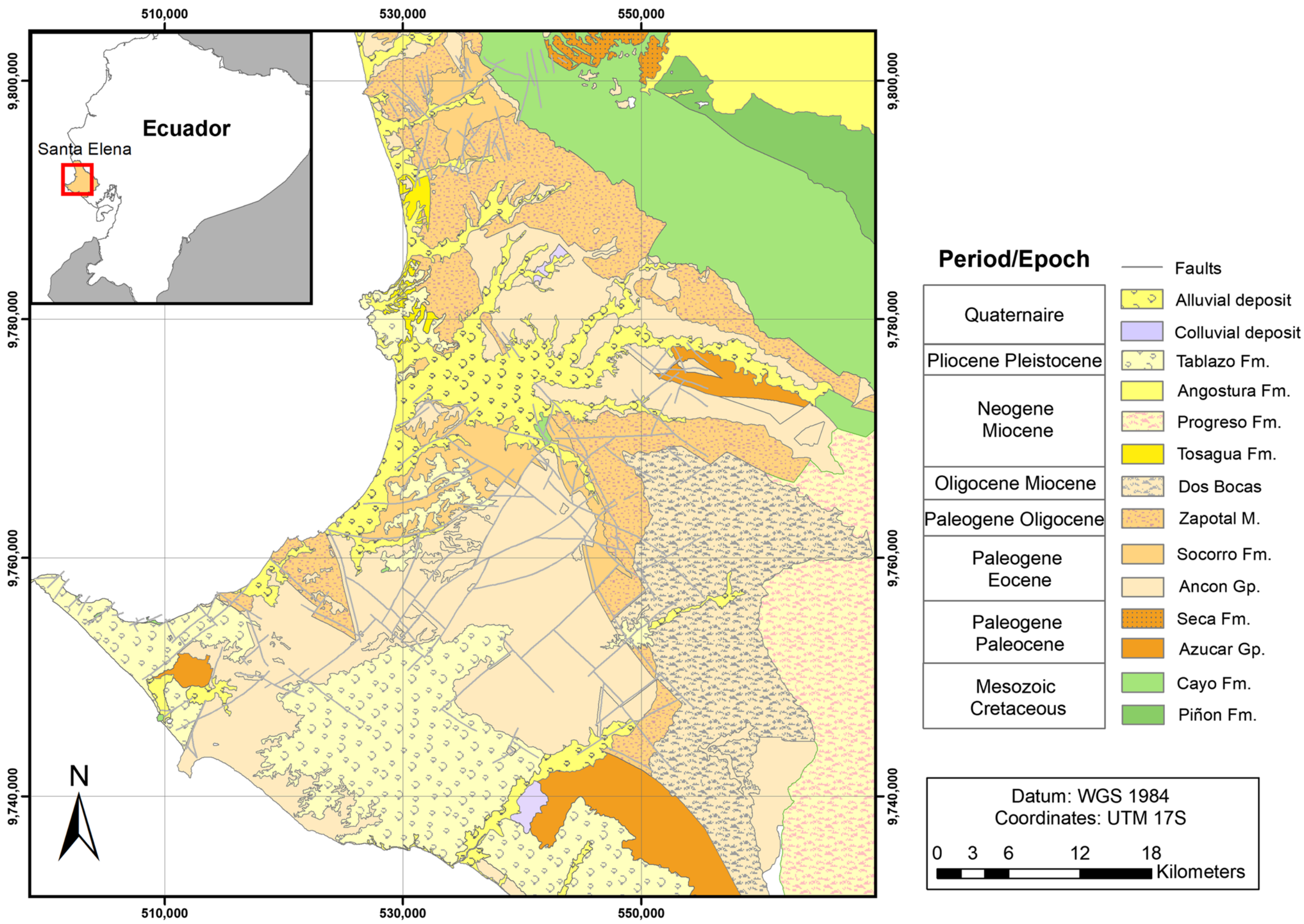
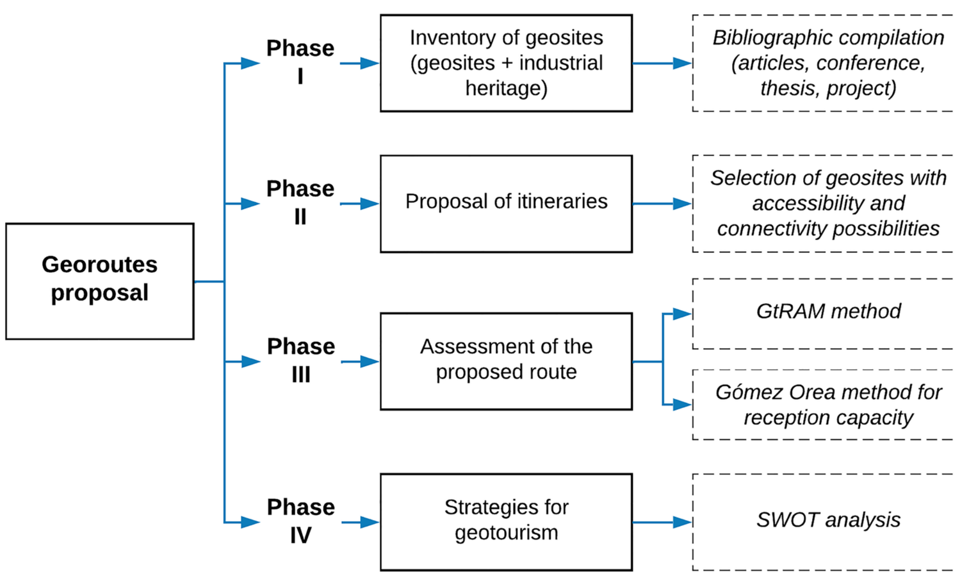


Fig. 2 Geological map of Santa Elena province, Ecuador. Based on (IIGE 2018)

Phase III: Assessment of the Proposed Routes

The third phase consisted of the quantitative evaluation of the georoutes to be analysed by the Geotouristic Route Assessment Matrix method (GtRAM, acronym in Spanish) (Carrión-Mero et al. 2021b). The GtRAM method is based on the information of sites registered as tourist sites by the Ministry of Tourism of Ecuador (MINTUR, acronym

Fig. 3 Methodological outline of the present study



in Spanish). This method can be applied comprehensively or globally for the assessment of georoutes and geotourism routes. The method assigns a value between 1 and 5 to each of the following parameters: accessibility, preparation and logistics, formal registration, heritage, contribution to science, and ecotourism, where 1–1.9 is considered "Low", 2–2.9 "Medium", 3–3.9 "High", and 4–5 "Very High".

The assessment is performed on each geosite, individually, and the assessment value of the georoutes is given by the average value of the individual scores.

In a second stage, we studied the overall reception capacity of the three routes based on the individual analysis of each geosite. Reception capacity is "an area's degree of adequacy or capacity for a certain activity, bearing in mind the effects of that activity on the environment" (Gómez Orea 2008; Gómez Orea and Gómez Villarino 2013), and it includes factors such as degree of suitability, land use, fragility, and potentiality. In summary, reception capacity assessment will determine the optimal land use according to its sustainability to know the impact of the activities on the different geological and landscape characteristics (Galacho Jiménez and Arrebola Castaño 2013; Fernández Gallardo et al. 2019).

The determination of the reception capacity was carried out in accordance with the Territorial Planning stage of the method of Gómez Orea (2008). It was qualified through a double-entry matrix with the geosites of each georoute on one axis and the different activities on the other. This matrix was designed based on the empirical (non-systematic) model of Gómez Orea's method, as it provides information about the implementation of activities according to the existing experience and knowledge in the study area. The matrix considers (Table 1) (i) potential activities, such as nature conservation (at geosites where the tourist is in direct contact with natural resources), tourism and recreation (at geosites where different tourist activities are permitted), tourist services (at geosites offering accommodation, restaurants, or tourist guides), tourism infrastructure (at geosites where civil work projects can be developed without altering the geological environment), industrial and economic (at geosites with capacity for industrial projects such as livestock farming, agriculture, fishing, oil exploitation); (ii) integration units (i.e. the proposed georoutes) used for the analysis or qualitative assessment of the reception capacity; (iii) assessment variables, such as Intrinsic current use (Vc after the Spanish acronym), Intrinsic use to introduce (Vi after the Spanish acronym), Compatible without limitations (C), Compatible with limitations (Cl), Compatibility subject to EIS (Environmental Impact Study) (Cs), Incompatible (I), and Not applicable (Na). One assessment variable is assigned to each intersection between row (i.e. integration units) and column (i.e. activities)—Table 1 shows a hypothetical example of the matrix. Therefore, the matrix indicates the location of each proposed activity, the georoutes, and the assessment of the implementation of the proposal according to different compatibility criteria.

Phase IV: SWOT Analysis

The fourth phase focused on geotourism development strategies through the SWOT analysis (Dyson 2004). This analysis also reveals, in general terms, the current condition of the geosites included in the Santa Elena Peninsula Geopark project.

Results

Inventory of Geosites

The study allowed us to identify 45 geosites, in the area, that have been assessed by at least one assessment method. The inventory is presented in Table 2.

Table 1 Example matrix for reception capacity analysis based on the Gómez Orea (2008) empirical model. ABC are hypotetical geosites of each georoute. *Vc*, Intrinsic current use; *Vi*, Intrinsic use to introduce; *C*, Compatible without limitations; *Cl*, Compatible with limitations; *Cs*, Compatible subject to EIS (Environmental Impact Study); *I*, Incompatible; and *N*, Not applicable. This table is only an illustration; the values do not represent real results of the study

			Activities				
			Nature conservation	Tourism and recreation	Tourist services	Tourism infrastructure	Industrial and economic
Integration units (Proposed georoutes)	GR-I	A		Vc		⋯	
		B				⋯	
		C	⋮	⋮	⋮	Na	⋮
	GR-II	A	Vi			⋯	Cs
		B	⋮	⋮	⋮	⋯	⋮
		C					Cl
	GR-III	A		C			
		B				⋯	
		C			I	⋯	

Table 2 Geosite inventory in the study area based on Sánchez Cortéz 2010; Herrera et al. 2018; Carrión et al. 2019; Herrera-Franco et al. 2020b. 1: IELIG method; 2: Barba et al. method; 3: GRECSIC method. *L*, Low; *M*, Medium; *H*, High; *VH*, Very High

Sites	Characteristic	Geosite type	Location (nearby population)	Assessment method and result		
				1	2	3
Acantilado de Anconcito	Mountain cliff	Stratigraphic	Anconcito-Ancón	VH		
Cerro Azúcar	Mountain	Structural	Azúcar	H		
Aguas Termales San Vicente	Natural spring	Hydrogeological	Baños San Vicente	H		H
Cueva de Aguas Profundas El Pelado	Cave	Geomorphological	Ayangue-Valdivia	H		
Acuífero Manglaralto	Aquifer	Hydrogeological	Manglaralto	VH	L	
Acantilado Olón	Mountain cliff	Geomorphological	Olón	H		
Acantilados Ballenita	Mountain cliff	Geomorphological	Ballenita	H		
Cascada Dos Mangas	Waterfall	Geomorphological	Dos Mangas	H		
Estructuras sedimentarias San Rafael	Sedimentary structure	Stratigraphic	San Rafael	H		
Terrazas Marinas Fm. Tablazo	Marine terrace	Geomorphological/Stratigraphic	Santa Elena	VH		
Playa de Bolsillo Ayangue	Beach	Geomorphological	Ayangue	H		
Playa Rosada	Beach	Geomorphological	Ayangue	H	H	
Acantilados Ayangue	Mountain cliff	Stratigraphic/ Morphological	Ayangue	H	H	
Estructuras Sedimentarias Ballenita	Sedimentary structure	Stratigraphic	Ballenita	H		
Islote el Pelado	Islet	Geomorphological	Ayangue/Valdivia	H	L	
Mirador Cerro Capay	Viewer	Geomorphological	Santa Elena	M		
Albarradas de Zapotal	Dam	Geomorphological	Zapotal	H		
Mirador de Montañita	View point	Geomorphological	Montañita	H		
Pozos de agua Manglaralto	Water well	Hydrogeological	Manglaralto	H		
Tapes en Olón	Dyke	Hydrogeological	Olón	H		
Acuífero Olón	Aquifer	Hydrogeological	Olón	H	L	
Cordillera Chongón-Colonche	Mountain Chain	Structural	Dos Mangas/El Suspiro	H		
Plataforma abrasión Ballenita	Platform	Stratigraphic	Ballenita	VH		
Acuífero Valdivia	Aquifer	Hydrogeological	Valdivia	H		
Cordillera Costera Chanduy-Playas	Mountain chain	Structural	Chanduy	H		
Afloramiento Lutitas Chocolate	Outcrop	Stratigraphic	Valdivia	H		
Fuente termal Borbollones	Natural spring	Hydrogeological	Borbollones	H		
Acuífero Río Chico	Aquifer	Hydrogeological	Manglaralto	M		
Torre El Suspiro	Tower	Geomorphological	El Suspiro	M		
Concreción Calcárea	Concretion	Stratigraphic	Santa Elena	H		
Fracturas secundarias rellenas de yeso	Filled fractures	Structural	Ayangue	H		
Marisma en Santa Paula	Swamp	Geomorphological	Salinas	M		
Vetillas de yeso Puerto Anconcito	Gypsum vents	Structural	Anconcito	VH		
Bad Lands Anconcito	Badlands	Geomorphological	Anconcito	VH		H
La Chocolatera	Geological formation	Geomorphological	Salinas	H	H	VH
Afloramiento Lutitas Diatomáceas	Outcrop	Stratigraphic	Santa Elena	H		
Afloramiento Areniscas Rojizas	Outcrop	Stratigraphic	Santa Elena	H		
Pozos Artesanales Atahualpa	Water well	Hydrogeological	Atahualpa	H		
Primer Pozo Petrolero	Oil well	Industrial (oil, Stratigraphic)	Ancón	H	M	VH
Mina San Rafael	Mine	Geo-industrial (mining)	San Rafael	H		
Salinas de San Pablo	Saline company	Geo-industrial (mining)	San Pablo	H		
Exudaciones Bituminosas La Libertad	Bituminous exudation	Sedimentary/Stratigraphic	La Libertad	H		
Exudaciones bituminosas Santa Paula	Bituminous exudation	Sedimentary/Stratigraphic	Salinas	H		H
Museo Paleontológico Megaterio	Museum	Palaeontological (ex-situ)	La Libertad	VH	VH	VH
Exudaciones Bituminosas Anconcito	Bituminous exudation	Sedimentary/Stratigraphic	Anconcito	H		

Most of the information on geosites was gained from initiatives within the framework of the Santa Elena Peninsula Geopark Project, coordinated by the Universidad Estatal Península de Santa Elena (UPSE) (Herrera et al. 2018; Herrera-Franco et al. 2020b). Other geosites were established by university initiatives such as academic theses (Sánchez Cortéz 2010) and research projects coordinated by CIPAT-ESPOL (Carrión et al. 2019).

The inventoried geosites (Table 2) are of varied typology, such as stratigraphic (20%), sedimentary (6.7%), hydrogeological (20%), geomorphological (33.3%), structural (11.1%), palaeontological (2.2%), and industrial heritage (6.7%). 51.1% of the geosites are located in the southern-central part of the province in the areas of Anconcito, Ancon, La Libertad, Santa Elena (urban), Ballenita, Chanduy, San Vicente, Azúcar, and Zapotal, while 48.9% is in the north, in the vicinity of the municipalities of Manglaralto, Olón, Valdivia, Ayangue, El Suspiro, and Dos Mangas.

In the inventory phase, we compared results obtained by three different methods (IELIG, Barba, and GREGSIC). The classification systems used by these methods (low, medium, high, and very high) were found to be consistent with each other and, thus, comparable. The results are shown in Table 2: (i) the IELIG method (acronym in Spanish, "Inventario Español de Lugares de Interés Geológico") (García-Cortés and Carcavilla 2013) was applied to assess 45 geosites, more than 90% of which obtained "high" and "very high" results, clearly demonstrating their scientific, educational, and touristic potential; (ii) the Barba et al. (1997) method was applied to eight geosites with an average "medium" value due to the lower scores in the management and tourism use of some geosites; and (iii) the Geological relevance, Representativeness, Geotouristically prominent Site, Interpretation, and Conservation (GREGSIC) method (Herrera-Franco et al. 2020b) yielded "high" and "very high" values for the assessed geosites, which means that there is geotourism potential in the surrounding communities.

Figure 4 shows some examples of the geosites inventoried in the study area: La Chocolatera (Fig. 4a), Exudaciones Bituminosas Santa Paula (Fig. 4b), Museo Paleontológico Megaterio (Fig. 4c), Primer Pozo Petrolero (Fig. 4d), Acantilado de Aconcito (Fig. 4e), Acuífero Manglaralto (Fig. 4f), Cascada Dos Mangas (Fig. 4g), Acantilado de Olón (Fig. 4h), and Tapes en Olón (Fig. 4i).

Itinerary Proposal

Based on the inventory, three itineraries or routes are proposed as strategic tools for geotourism development: GR-I, GR-II, and GR-III (see Fig. 5 and Supplementary Material A).

- In the southeast, GR-I (Fig. 5a) consists of five geosites of different typologies (i.e. one geomorphological, two structural, one hydrogeological, and one mining industrial type). The itinerary is a 68.6 km long route that takes approximately 1 day to complete (including travel and site visits). Access to the itinerary is via the Guayas-Santa Elena road. The geosites of the itinerary, all located in the Santa Elena canton, are "Albarradas de Zapotal", "Cerro El Azúcar", "Aguas Termales San Vicente", "Cordillera Chanduy-Playas", and "Mina San Rafael".

The GR-I route starts with a visit at the dam of the "Albarradas de Zapotal" geosite. The second stop, at a distance of 12.2 km, is the "Cerro El Azúcar" geosite with a panoramic view of the geological structures of the Chongón Colonche Mountain Range, followed by the natural springs of the "Aguas Termales San Vicente" geosite, 4 km away from the "Cerro". Finally, the last two stops are the "Cordillera Chanduy-Playas" geosite displaying spectacular geoforms and the "Mina San Rafael", which presents minerals from this mountain range.

- In the southwest, GR-II (Fig. 5b) consists of 12 geosites with different typologies (i.e. one hydrogeological, two stratigraphic, two industrial (oil and mining industry, respectively), four geomorphological, one structural, one sedimentary, and one palaeontological). This route extends over all three cantons of the province (Santa Elena, La Libertad, Salinas) and has two accesses in the eastern part of the province: one at the Guayas-Santa Elena road and one at the Manabí-Santa Elena road. GR-II has a total distance of 102.9 km, and the visit takes 2 days to complete by car. The geosites are "Pozos Artesanales Atahualpa", "Acantilado de Anconcito" (Fig. 4e), "Primer Pozo Petrolero" (Fig. 4d), "Bad Lands Anconcito", "Vetillas de yeso Puerto Anconcito", "Exudaciones bituminosas Santa Paula" (Fig. 4b), "Marisma en Santa Paula", "La Chocolatera" (Fig. 4a), "Museo Paleontológico Megaterio" (Fig. 4c, "Terrazas Marinas Fm. Tablazo", "Plataforma abrasión Ballenita", and "Salinas de San Pablo".

The itinerary starts at the "Pozos Artesanales Atahualpa" geosite with shallow wells drilled to supply water, followed by the "Acantilado de Anconcito" geosite, a coastal cliff composed mainly of clays and shales of high porosity. In the same area, 4.8 km farther off along the road, is the "Primer Pozo Petrolero" (First Oil Well) geosite considered a cultural heritage site of Ecuador. At a distance of 6.6 km, within the village of Anconcito, are the geosites "Bad Lands Anconcito" and "Vetillas de yeso Puerto Anconcito" where structural and geomorphological reliefs of the Ancon-Anconcito cliff can be observed. Twelve kilometers away to the west are the "Exudaciones bituminosas Santa Paula"

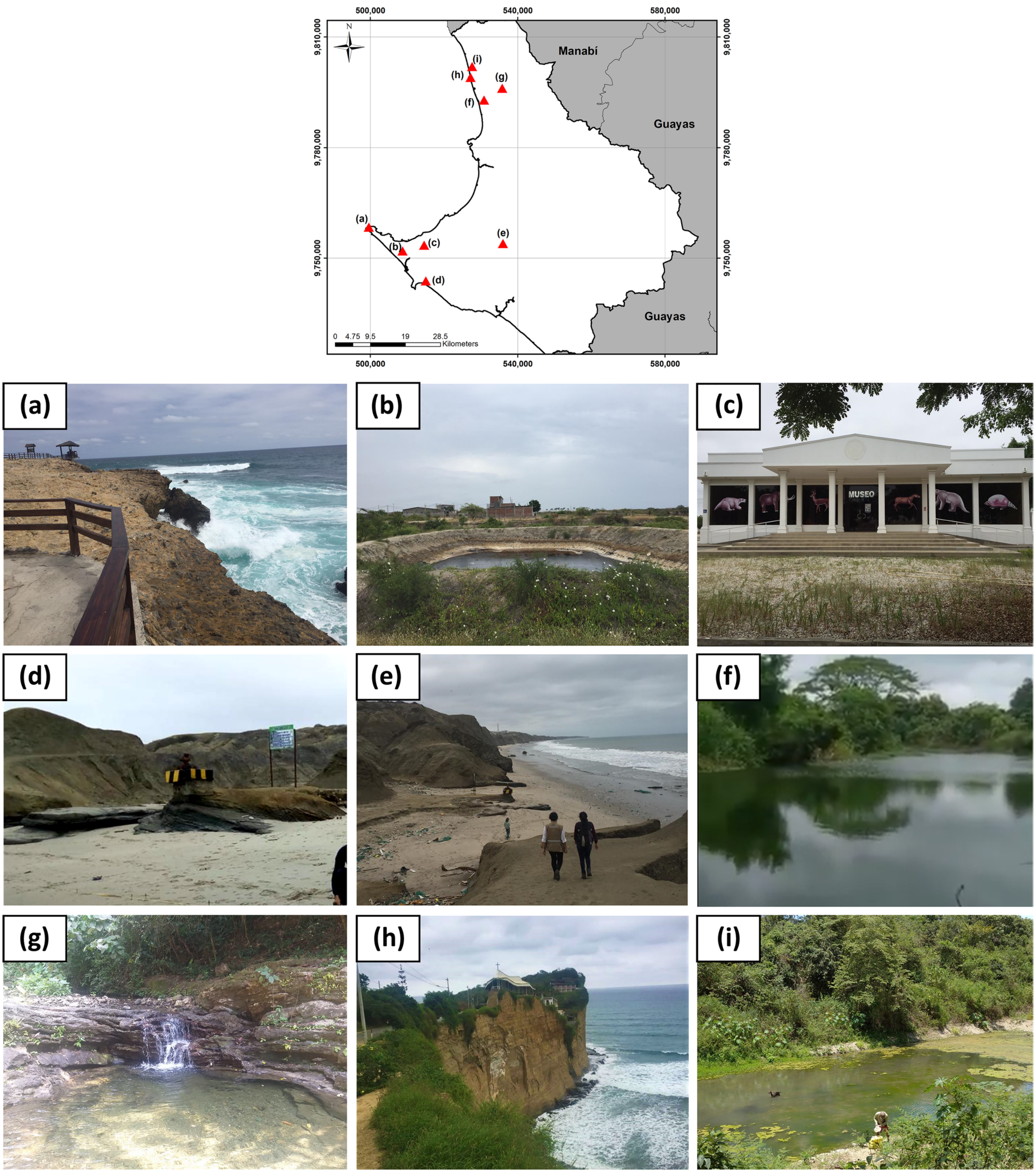


Fig. 4 Geosites in the Santa Elena province: (**a**) La Chocolatera; (**b**) Exudaciones bituminosas Santa Paula; (**c**) Museo Paleontológico Megaterio; (**d**) Primer Pozo Petrolero; (**e**) Acantilado de Anconcito; (**f**) Acuífero Manglaralto; (**g**) Cascada de Dos Mangas

and "Marisma en Santa Paula" geosites with a natural bituminous outcrop and marine geomorphology. The tour continues at the "La Chocolatera" geosite, which is the highest point of Ecuador, with rocky geomorphology of shales, clays, and limestones of the Cayo formation (Bolívar 2011). The next stop is the "Museo Paleontológico Megaterio" in La Libertad canton, which exhibits animal remains of the Late Pleistocene Megafauna. 8.5 km away, in

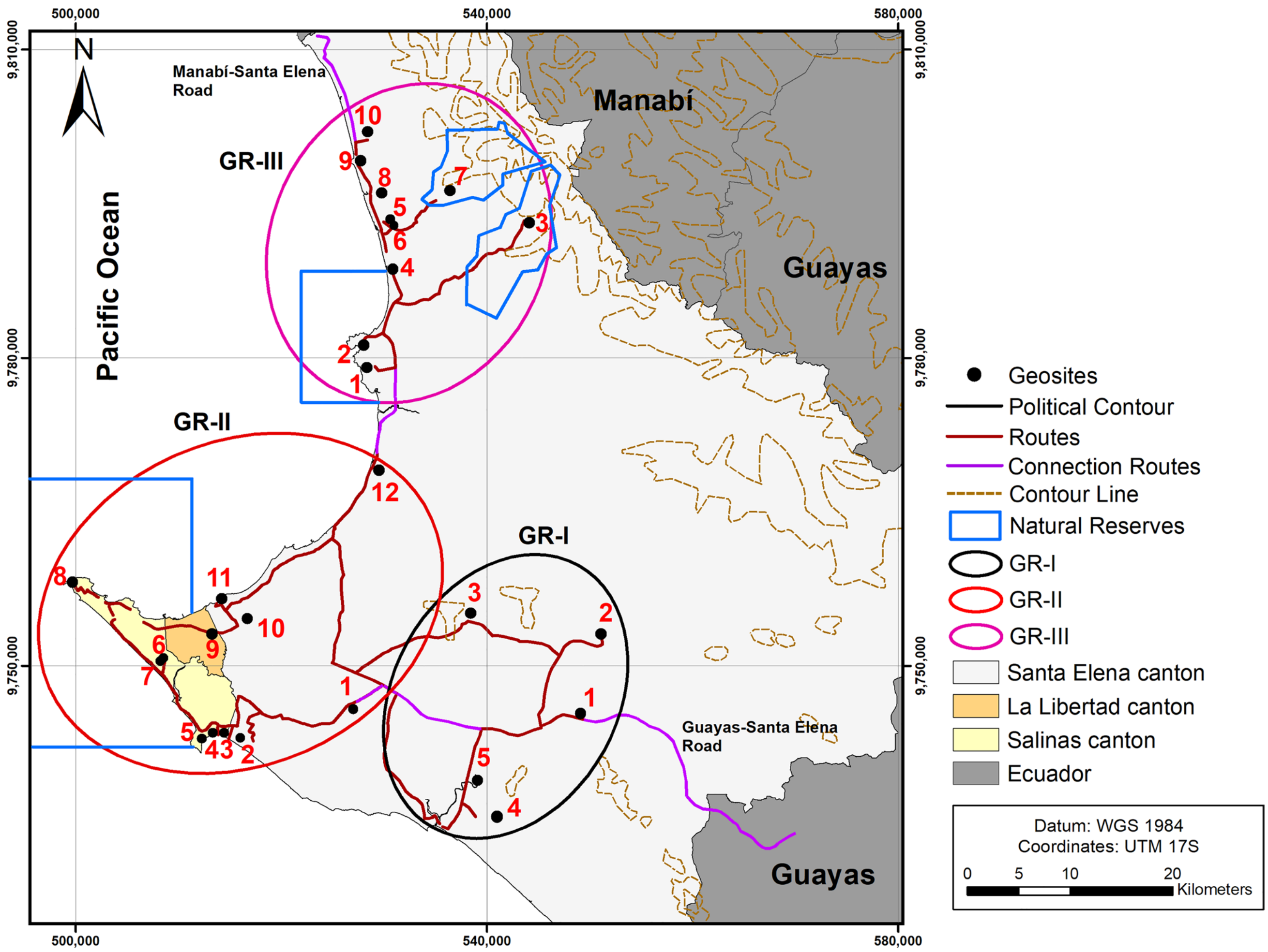


Fig. 5 Detail of the geosites of the three georoutes. (**a**) GR-I (1. Albarradas de Zapotal, 2. Cerro Azúcar, 3. Aguas Termales San Vicente, 4. Cordillera Costera Chanduy-Playas, 5. Mina San Rafael); (**b**) GR-II (1. Pozos Artesanales Atahualpa, 2. Acantilado de Anconcito, 3. Primer Pozo Petrolero, 4. Bad Lands Anconcito, 5. Vetillas de yeso Puerto Anconcito, 6. Exudaciones bituminosas Santa Paula, 7. Marisma en Santa Paula, 8. La Chocolatera, 9. Museo Paleontológico Megaterio, 10. Terrazas Marinas Fm. Tablazo, 11. Plataforma abrasión Ballenita, 12. Salinas de San Pablo); (**c**) GR-III (1. Playa Rosada, 2. Playa de Bolsillo Ayangue, 3. Torre El Suspiro, 4. Acuífero Valdivia, 5. Acuífero Manglaralto, 6. Pozos de agua Manglaralto, 7. Cascada Dos Mangas, 8. Mirador de Montañita, 9. Acantilado Olón, 10. Tapes en Olón)

the Santa Elena canton, we can visit the "Terrazas Marinas Fm. Tablazo" and "Plataforma abrasión Ballenita" geosites with a geomorphology of sands (calcareous and fine) and clays. Finally, the route ends at the "Salinas de San Pablo" geosite in the north of the province, where mineral salts are extracted.

- GR-III (Fig. 5c), in the northern part of the province, comprises ten geosites, 20% of which are on the coast (beaches) and 80% are inland (mountains, rivers, waterfalls, aquifers). These geosites are of two typologies (i.e. six geomorphological and four hydrogeological). The itinerary covers a distance of 71.3 km that could be completed by car in 2 days. It can be reached either via the Guayas-Santa Elena road or by the Manabí-Santa Elena road. This georoute includes both asphalt roads and unpaved paths that could also be travelled on foot or on horseback. In this case, the total travel time would be of 3 days. Its geosites, all located in the north of Santa Elena canton, are "Playa Rosada", "Playa de Bolsillo Ayangue", "Torre El Suspiro", "Acuífero Valdivia", "Acuífero Manglaralto" (Fig. 4f), "Pozos de agua Manglaralto", "Cascada Dos Mangas" (Fig. 4g), "Mirador de Montañita", "Acantilado Olón" (Fig. 4h), and "Tapes en Olón" (Fig. 4i).

The GR-III itinerary starts at the "Playa Rosada" geosite, a beach with an extension of 730 m that displays a unique geomorphology due to the accumulation of sediments by waves, river currents, and wind (González Artieda et al. 2012). In the same area, 9.5 km away, is the "Playa de Bolsillo Ayangue" geosite, with sediments surrounded by clay cliffs. Then, the route continues to the east. At the

"Torre El Suspiro" geosite, we can observe the geoforms of the Chongón Colonche Mountain Range. Returning to the coast, we can find the "Acuífero Valdivia" geosite with a hydrogeological system that allows water accumulation on the surface. The next stops, to the north, are the "Acuífero Manglaralto" geosite with another hydrogeological system (Morante et al. 2019; Herrera-Franco et al. 2020a) and the "Pozos de agua Manglaralto" drilled to supply water to the surrounding communities. Then, at a distance of 6.9 km, there is the "Cascada Dos Mangas" geosite, which offers several attractions, such as the geoforms of the Chongón Colonche Mountain Range and a complex water system (rivers, waterfalls, and lakes). The route continues at the "Mirador de Montañita" geosite, followed by the "Acantilado Olón" with spectacular geomorphology of stiff clays. Finally, the GR-III route ends at the "Tapes en Olón" geosite, which is of hydrogeological interest.

All three georoutes tour begin on the main Guayas-Santa Elena road. GR-I's last site ("Mina San Rafael") is also on the same road, so the visit can be continued directly with GR-II's "Pozos Artesanales Atahualpa" geosite. Once finishing GR-II, there is a road that connects its last site ("Salinas San Pablo") with the starting site of GR-III ("Playa Rosada"). Therefore, it is possible to complete the three georoutes together.

In addition, we designed alternative shorter routes ("sightseeing itineraries") to visit some of the most prominent geosites (see Supplementary Material B), which also offer representative geological variety.

Quantitative Assessment with the GtRAM Method

The five geosites of GR-I (Fig. 6a) obtained the following scores in the GtRAM method assessment: one "high" value (Aguas Termales San Vicente), one "medium" value (Museo Real Alto), and three "low" values (Mina San Rafael, Cordillera Costera Chanduy-Playas, Cerro Azúcar). The overall assessment of the route yielded an average of 2.16/5, which is an "average" score.

GR-II (Fig. 6b) comprises 12 geosites with the following scores according to the GtRAM method: one "very high" value (La Chocolatera with 4.39/5); one "high" value (Museo Paleontológico Megaterio); nine "medium" values (Atahualpa Artisanal Wells, Anconcito Cliff, First Oil Well, Puerto Anconcito Gypsum Veins, Santa Paula Marsh, Santa Paula Bituminous Ooze, Tablazo Fm. Marine Terraces, Ballenita Abrasion Platform, and San Pablo Salt Flats); and one "low" value (Bad Lands Anconcito). Therefore, the average score of GR-II is 2.68/5, which is an "average" value.

Of the ten geosites of GR-III (Fig. 6c), five geosites obtained "high" scores (Playa de Bolsillo Ayangue, Manglaralto Aquifer, Manglaralto Water Wells, Dos Mangas Waterfall, Olon Cliff), three obtained "medium" values (Valdivia Aquifer, Montañita Viewpoint, Tapes in Olon), and one geosite obtained a "low" value (Playa Rosada). This georoute (GR-III) has an average of 2.74/5, which is also an "average" value.

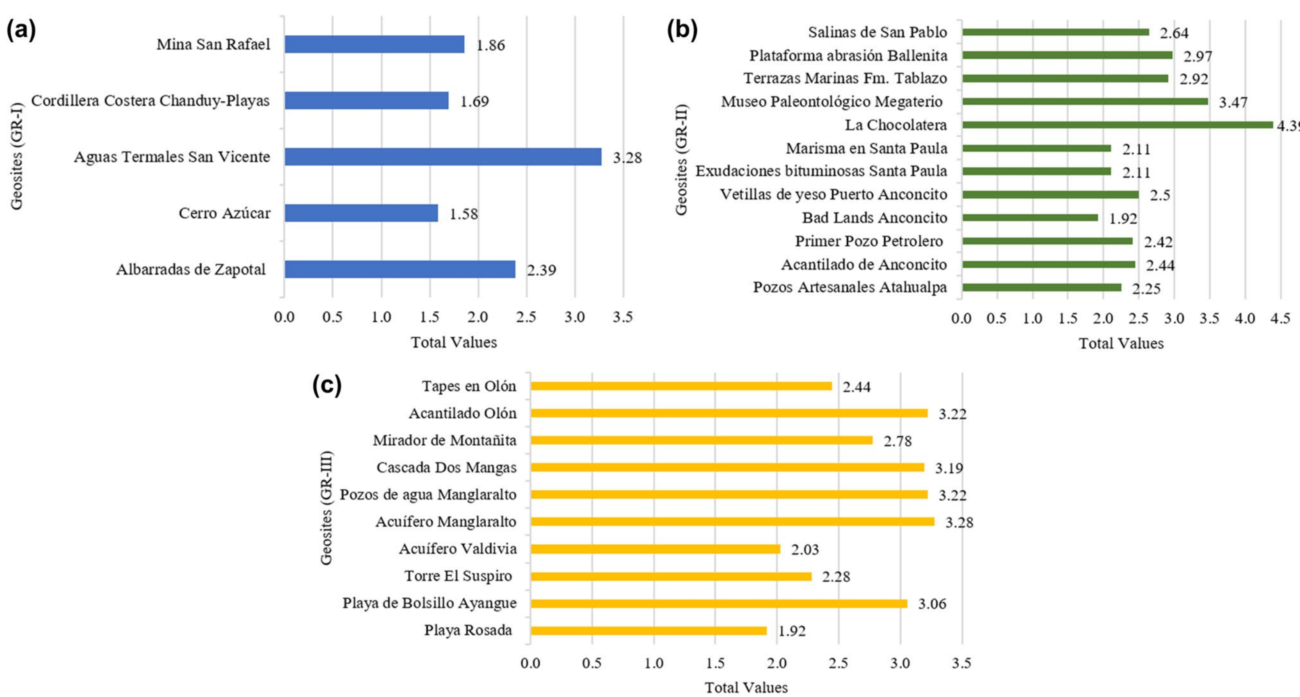


Fig. 6 Results of evaluation with the Geotouristic Route Assessment Matrix method (GtRAM, acronym in Spanish) (Carrión-Mero et al. 2021b) for the geosites of (**a**) GR-I, (**b**) GR-II, and (**c**) GR-III

Figure 7 shows the eight geosites that obtained the highest scores (their average is 3.39/5): one belongs to GR-I ("Aguas Termales San Vicente"), two of them to GR-II ("La Chocolatera", "Museo Paleontológico Megaterio"), and the rest is part of GR-III. The sites of GR-III (Playa de Bolsillo Ayangue, Acuífero Manglaralto, Pozos de agua Manglaralto, Cascada Dos Mangas, Acantilado Olón) obtained "high" and "very high" values, in variables such as "Preparation and logistics", "Registration with the Ministry of Tourism", and "Ecotourism".

Reception Capacity

The determination of the reception capacity of the territory by Gómez Orea's empirical model (2008) is presented in Fig. 8 and Table 3. The five main activities identified and assessed in this study are described here:

- Nature Conservation activity (A): we found that 85.2% of the geosites already have or could have a intrinsic use that is environmentally compatible (values Vc, Vi, and C in Table 3). Nature conservation is an activity of utmost importance at geosites where tourists are in direct contact natural resources. On the other hand, this activity does not apply to 14.8% of the geosites (e.g. Museo Paleontológico Megaterio or Primer Pozo Petrolero).

- Tourism and Recreation activity (B): 29.6% of the geosites already host tourist activities (values Vc in Table 3). The sites that obtained Vi and C values (62.9%) are prepared to receive tourist and recreational activities. In general, the territory has a tourist and recreational potential that can be exploited. However, there are at least two geosites (Torre El Suspiro and Cascada Dos Mangas), where the delicate natural environment requires a strict environmental control for tourist activities.

- Tourism Services activity (C): 85.2% of the geosites already have or could have an intrinsic use (Vc + Vi) and are compatible (C) with the proposal (Table 3). However, there are four geosites (14.8%) with limited compatibility (Cl) or in need of an EIS (Environmental Impact Study) (Cs) in projects of tourism services (Table 3). This is particularly true for those geosites that have a natural vulnerability or are located in nature reserves.

- Tourism Infrastructure activity (D): 22.2% of geosites have already applied infrastructure projects (values Vc in Table 3), and 48.1% are eligible for future infrastructure projects (values Vi in Table 3). An additional four geosites (14.8%) have no limitations regarding this activity (value C in Table 3). Some natural sites (14,8%), however, would require environmental analysis to avoid negative effects on the natural environment (values Cl + Cs).

- Industrial and Economic activity (E): there are geosites with an industrial character and capacity for economic development (values Vc in Table 3). However, most geosites are not compatible with this activity, as the natural environment would be affected or destroyed (values Cl, I, and Na in Table 3).

SWOT Analysis

The SWOT matrix analysis considered the results of the previously developed reception capacity assessment. The analysis (Table 4) revealed that geotourism development in the province is possible through the implementation of strategic (cultural-natural) activities, links with financial entities (both private and public), and geotourism promotion campaigns at the national and international levels (geoparks, georoutes). The ultimate goal is to foster geotourism development and generally boost the economy in the Santa Elena province.

The mentioned strategies must specifically address geosites that obtained a lower assessment score, particularly the Cerro Azúcar, Cordillera Costera

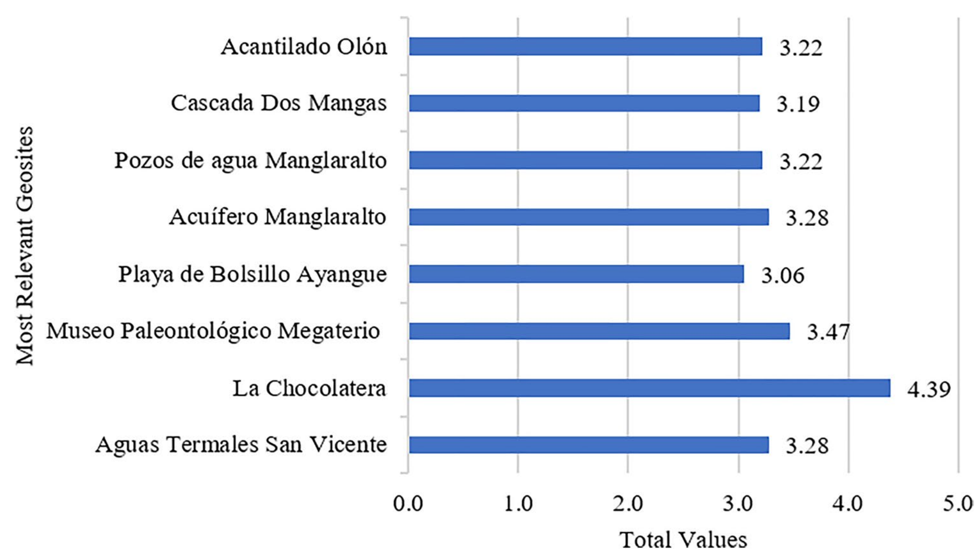


Fig. 7 Geosites of the three georoutes that obtained the highest scores of the GtRAM method

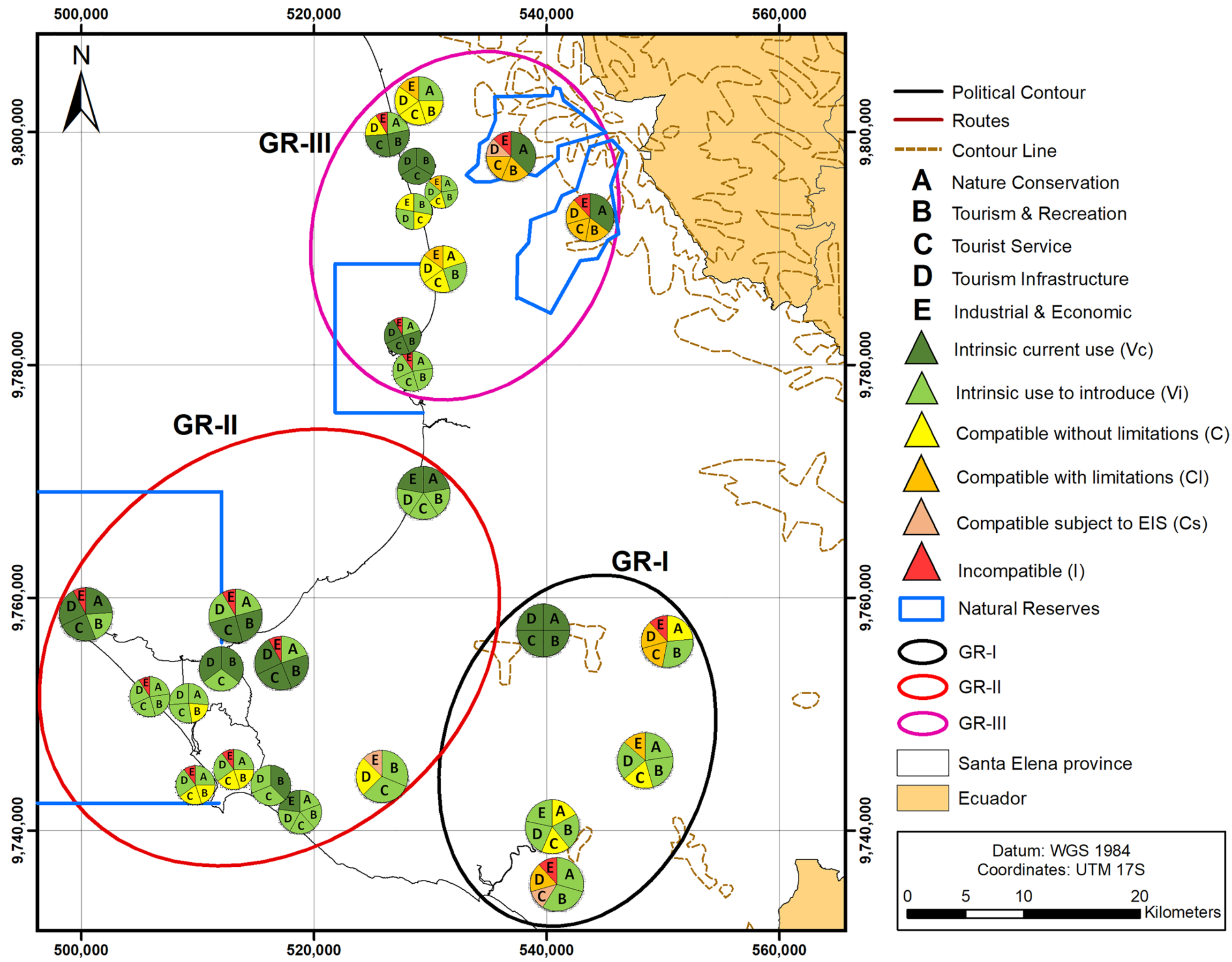


Fig. 8 Reception capacity of the proposed georoutes: (**a**) GR-I, (**b**) GR-II, and (**c**) GR-III. According to Gómez Orea (2008) method

Chanduy-Playas, Playa Rosada, Mina San Rafael in GR-I; Pozos Artesanales Atahualpa, Acantilado de Anconcito, Primer Pozo Petrolero, Bad Lands Anconcito, Marisma en Santa Paula, Exudaciones bituminosas Santa Paula in GR-II; and Playa Rosada, Acuífero Valdivia, Mirador de Montañita, and Tapes en Olón in GR-III. They must also build on academic research projects (geoparks) and governmental plans (road maintenance, geosite infrastructure, and environmental protection campaigns) related to the geotourism development of the province.

Besides the strengths and opportunities, weaknesses were identified at more than 40% of the geosites. The lack of tourism infrastructure, lack of road maintenance projects, and non-existent logistic control create problems for tourism development at the local level. In addition, there are no environmental conservation activities in vulnerable sites, such as geosites located in nature reserves (e.g. Torre El Suspiro, Cascada Dos Mangas). The SWOT analysis also encountered a lack of tourism infrastructure maintenance, a reduction in government support, and a low tourism index due to the COVID-19 pandemic at the geosites that are already popular tourist destinations (e.g. La Chocolatera, Museo Paleontológico Megaterio).

Interpretation of Results and Discussions

The geotourism potential of the Santa Elena province has already been demonstrated by previous assessment studies (Sánchez Cortéz 2010; Herrera et al. 2018; Herrera-Franco et al. 2020b), which provided a basis for the proposal of georoutes (Fig. 5). These evaluation methods (e.g. IELIG (García-Cortés and Carcavilla 2013), Barba et al. (1997), GREGSIC (Herrera-Franco et al. 2020b)) have been used in Ecuador and other countries worldwide to determine the global interest of geosites from a geological, cultural, heritage, and geotourism perspective (e.g. Corbí et al. 2018; Morante-Carballo et al. 2020).

Table 3 Reception capacity analysis of the proposed georoutes according to the Gómez Orea (2008) method. *Vc*, Intrinsic current use; *Vi*, Intrinsic use to introduce; *C*, Compatible without limitations; *Cl*, Compatible with limitations; *Cs*, Compatible subject to EIS (Environmental Impact Study); *I*, Incompatible; *Na*, Notapplicable

Georoutes	No	Geosites	Activities				
			Nature conservation	Tourism and recreation	Tourist service	Tourism infrastructure	Industrial and economic
GR-I	1	Albarradas de Zapotal	Vi	Vi	C	Vi	Cl
	2	Cerro Azúcar	C	Vi	Cl	Cl	I
	3	Aguas Termales San Vicente	Vc	Vc	Vc	Vc	Na
	4	Cordillera Costera Chanduy-Playas	Vi	Vi—C	Cs	Cl	I
	5	Mina San Rafael	C	Vi-Cl	C	Vi-Cl	Vi-Cl
GR-II	1	Pozos Artesanales Atahualpa	Na	Vi	Vi-C	C	Cs
	2	Acantilado de Anconcito	Vi	Vi	Vi	Vi	Vc-Cl
	3	Primer Pozo Petrolero	Na	Vc	Vi	Vi	Na
	4	Bad Lands Anconcito	Vi	C	C	Vi	I
	5	Vetillas de yeso Puerto Anconcito	Vi	C	C	Vi	I
	6	Exudaciones bituminosas Santa Paula	Vi	C	Vi-C	Vi-C	Na
	7	Marisma en Santa Paula	Vi	Vi-Cl	Vi-Cl	Vi-Cl	I
	8	La Chocolatera	Vc	Vi	Vc	Vc	I
	9	Museo Paleontológico Megaterio	Na	Vc	Vi	Vc	Na
	10	Terrazas Marinas Fm. Tablazo	Vi	Vc	Vc	Vc	I
	11	Plataforma abrasión Ballenita	Vi	Vc	Vc	Vi	I
	12	Salinas de San Pablo	Vc	Vi-Cl	Vi	Vi-Cl	Vc
GR-III	1	Playa Rosada	Vi	Vi-C	Vi	Vi	I
	2	Playa de Bolsillo Ayangue	Vi	Vc	Vc	Vc	I
	3	Torre El Suspiro	Vc	Cl	Cl	CI	I
	4	Acuífero Valdivia	C	Vi	C	C	Cl
	5	Acuífero Manglaralto	Vi	Vi-Cl	C	Vi	Cl
	6	Pozos de agua Manglaralto	Na	Vi	C	Vi	C
	7	Cascada Dos Mangas	Vc	Cl	Cl	Cs	I
	8	Mirador de Montañita	C	Vc	Vc	Vc	Na
	9	Acantilado Olón	Vi	Vc	Vc	C	I
	10	Tapes en Olón	Vi	C	C	C	Cl

Although the Ecuadorian government has recently proposed a tourist route, known as the Spondylus route (Ministerio de Transporte y Obras Públicas 2013), in the province, our aim was to create strategic itineraries with significant scientific, educational, and tourism values seeking the development of local communities. Similar initiatives have been published in other provinces of the country by the CIPAT-ESPOL research group (Carrión-Mero et al. 2021b, a).

The GtRAM method application yielded an "average" value (2.66/5) of the global assessment of the three routes. In general terms, this result is a product of the "high" and "very high" values in parameters such as accessibility, heritage, and contribution to scientific knowledge, and the "medium" and "low" values in parameters such as preparation and logistics, and ecotourism. The results of the methods compiled in the first phase (IELIG, Barba, and GRECSIC) are more favourable than the GtRAM results, for most geosites. These positive values reflect the scientific and academic interest, management, and tourist use (IELIG and Barba), as well as the geological and didactic representativeness (GRECSIC). On the other hand, the GtRAM method showed that more than 50% of the geosites in each georoute have a "low" and "medium" value due to their lack of legal support (i.e. assistance from the Ministry of Tourism) and environmental protection activities (voluntary campaigns, publicity, signage). Therefore, it is crucial to promote legal support and environmental protection by the competent administration to solve the problems detected at some geosites (e.g. Cerro Azúcar, Cordillera Costera Chanduy-Playas, Bad Lands Anconcito, Exudaciones bituminosas Santa Paula, Marisma en Santa Paula, Playa Rosada, Acuífero Valdivia, Tapes en Olón). This could include the application of the Ecuador Tourism

Table 4 Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the proposed georoutes

Internal factors	Strengths	Weaknesses
External factors	1. Geosites with unique characteristics at the national level 2. Variety of attractive geological scenarios 3. Ancon is part of Ecuador's cultural heritage 4. Geosites with potential for educational and tourist use 5. Active national and international tourism in the province 6. The reception capacity indicates that the routes and their exploitation would not have a negative impact on the territory	1. Unpaved roads and other logistical difficulties in reaching geosites 2. Some geosites do not have an appropriate infrastructure 3. Lack of tour guides 4. Lack of links with the Ministry of Tourism 5. No environmental conservation activities
Opportunities	**Strengths + opportunities**	**Weaknesses + opportunities**
a. Creation of a geopark for sustainable development through geotourism b. Promotion of cultural activities as an economic strategy in the province c. Territorial plan for the province including new tourist destinations d. Expansion of tourist offer based on geosite-related scientific knowledge	1.3.4.a. Heritage recognition of geosites with high natural and cultural value 2.3.b.c. Scientific and tourism activities at less popular geosites 1.2.4.5.6.a.b.d. Promotion of new forms of tourism such as geoparks and georoutes	4.b.c.d. Scientific and tourism development 2.3.a.c. New economic resources for asphalt and road infrastructure projects through cultural and natural use 4.5.a.c. Closer links between academia, local communities and governmental bodies
Threats	**Strengths + threats**	**Weaknesses + threats**
a. Lack of maintenance investment in geosites with tourism potential b. Lack of financial support from governmental entities c. Low tourism index due to COVID-19 pandemic	2.4.c. Strategic plan for geosites as open spaces for economic reactivation	1.a.b. Georoute promotion through collaboration between interested parties 1.2.5.a. Strategies for environmental protection in geosites with natural diversity

Development Law (Asamblea Nacional del Ecuador 2014), the "Plan de Desarrollo y Ordenamiento Territorial" (PDOT, acronym in Spanish) (GAD Santa Elena 2015), and sustainable development initiatives in vulnerable areas. Having tackled these issues, the selected sites have an outstanding tourist potential. Still, they inevitably need an investment input that is basic and strategic for their development.

The assessment results from Vc, Vi, and C were considered positive in this study, meaning that activities qualified with either of these values are suitable for the georoute proposal, as the activity is already present at the site or is sustainable and adaptable to the site environment. The reception capacity showed that 85.2% of geosites are in intrinsic use and are compatible with the proposal, which also means that the proposed tourist use would not have a negative effect on the environment, at most geosites. On the other hand, the variables Cl and Cs were considered to require a complementary study (e.g. environmental impact assessment) because the activities have limited or null compatibility with the environmental aspect of the geosite in question. At some geosites, therefore (e.g. Torre El Suspiro, Cascada Dos Mangas), activity (i.e. infrastructure development, tourism services, tourism, and recreation activities) should be limited in accordance with the outcome of detailed compatibility studies and environmental impact studies. The creation of georoutes under these conditions would favour conservation and promote tourism at the local level. Finally, it must be noted that "incompatible" values (13 out of 27) were only found for potential industrial and economic activities, which are not contemplated in the proposed plan.

GR-I was found to have an appropriate global reception capacity; however, certain geosites must have limited tourism services and infrastructure (e.g. Cerro El Azúcar, Mina San Rafael) and other sites would require an environmental impact study for large-scale projects in order to avoid any alteration in the natural environment (e.g. Cordillera Costera Chanduy-Playas). GR-II has the highest reception capacity among the proposed itineraries, which makes it a real opportunity regarding geotourism development. Industrial and economic activity could present a threat to the environment, as in the province, some industrial activities take place near or within sites with a higher degree of protection. Therefore, synergies of criteria and strategies with citizen participation are needed. In addition, some geosites obtained Cl values for tourism activities due to the presence of diverse marine-terrestrial fauna and a vulnerable geological environment (e.g. Marisma en Santa Paula, Salinas de San Pablo). Finally, GR-III is compatible with tourism development projects, but they require a legislative proposal and environmental control by administrative bodies. In this itinerary, there are geosites located in nature reserves, such as Cascada Dos Mangas and Torre El Suspiro, that obtained Cl and Cs values in tourist activities due to the diversity of their flora and fauna.

Although the SWOT analysis indicates that the proposed georoutes can contribute to geotourism development, there exist some weaknesses and threats that may present difficulties. The main weaknesses are caused by the lack of logistics and tourism projects. The involved universities propose a series of technical initiatives to be used by local and provincial administrations to overcome these barriers. In addition, threats identified in the SWOT analysis, such as inadequate funding, can be addressed through a strategic economic revival plan, together with georoute promotion and environmental conservation activities. Socioeconomic development proposals have been implemented by universities (e.g. Arce Bastidas et al. 2020) and governmental entities (e.g. Tourism & Leisure 2007; GAD Santa Elena 2015) with favourable results in urban and rural communities. The studies addressed in this initiative are the ones that will allow, in the future, to improve the effectiveness and broaden the scope of projects focused on local development through the use of its natural resources.

Conclusions

This work compiled the sites of significant geological interest in the Santa Elena province in order to select the most suitable ones for the creation of geotourism itineraries or georoutes. The selected geosites are of varied typology: mountains, aquifers, natural springs, beaches, dams, viewpoints, badlands, outcrops, bituminous exudations, one mine, one museum, and an oil well. The proposed georoutes represent an alternative for territorial development, as they offer real possibilities for geotourism activities with socioeconomic implications for the local population. Therefore, natural and cultural heritage are strategically combined and strengthen the proposal.

Although there are routes promoted by other academic works and governmental projects (Spondylus route), our aim was to create strategic itineraries (GR-I, GR-II, and GR-III) with significant scientific, educational, and tourism values seeking territorial development. The GtRAM method measures geotourism potential based on the assessment of tourism features. According to this method, the georoutes currently have a “medium” potential for geotourism, which could benefit the socioeconomic development of places far from the usual tourist trails, i.e. geosites that currently do not have a significant number of visitors. Furthermore, the reception capacity analysis indicated that the proposed tourism activities would not create a significant environmental impact, as in 85.2% of the cases they are already present or are compatible with the environmental protection of the geosites. Other activities, like industrial and economic activities, could be harmful to these sites; therefore, appropriate control and protection measures must be employed in these activities using the information offered here.

The proposed routes (georoutes) were developed considering international criteria applied in geopark projects. The itineraries also aim to integrate the different cultural values of the Santa Elena province, such as gastronomy, traditional techniques, fauna, industrial history, and places of natural significance.

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