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COASTAL GEOMORPHOSITES OF THE ISLES OF LIPARI AND STROMBOLI (AEOLIAN ISLANDS, ITALY): NEW POTENTIAL FOR GEO-TOURISM

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ABSTRACT: F. Geremia & R. Massoli-Novelli, *Coastal geomorphosites of the Isles of Lipari and Stromboli (Aeolian islands, Italy): new potential for geo-tourism.* (IT ISSN 0394-3356, 2005).
After illustrating the main geological, volcanological and geomorphological characteristics of the Aeolian Islands and, in particular, of Lipari and Stromboli – the two main isles of the archipelago – their most important coastal geomorphosites are individuated. Considering their high level of geological and geomorphological interest, two geo-tourism itineraries by boat are planned – one for each island – to promote their coastal landscape of volcanic origin. Six coastal geomorphosites or groups of geomorphosites of elevated scientific and educational value are selected for each itinerary.
The itinerary for the island of Lipari begins in its eastern side with a panoramic view of the famous Castle of Lipari, built on a imposing rhyolitic lava dome. It continues toward the northern coast, where there are considerable pumice quarries and a rare coarse clastic beach, characterized by the presence of dark volcanic gravels and pebbles and light-coloured pebbles of pumice, to finish in the southern side with the observation of two notable volcanic pinnacles (Pietralunga and Pietra Menalda).
The itinerary for the island of Stromboli begins from the pier of Scari, characterised from a dark-coloured sandy beach and continues toward Ginostra, where it is possible to run along the first geological-historical path of Aeolian Islands. The itinerary continues toward northwest with the impressive panoramic view of the "Sciara del Fuoco", a rare landscape in the Mediterranean, and to finish around the neck of Strombolicchio, the last evidence of a vast volcanic edifice.
Emphasis is given to the importance of this new kind of cultural tourism, named "geo-tourism", according the principles of sustainable development and based on the promotion and conservation of the unique geomorphological-volcanological heritage of Aeolian islands.

RIASSUNTO: F. Geremia & R. Massoli-Novelli, Geomorfositi costieri delle Isole Lipari e Stromboli (Isole Eolie, Italia): una nuova potenzialità per il turismo*. (IT ISSN 0394-3356, 2005).*
Dopo la illustrazione delle principali caratteristiche geologiche, vulcaniche e geomorfologiche delle Isole Eolie in generale ed in particolare di Lipari e Stromboli, le due principali isole dell'arcipelago, ne vengono individuati i principali geomorfositi costieri.
In base alle valenze geologiche-geomorfologiche identificate vengono progettati due itinerari geoturistici, uno per isola, da dedicare al paesaggio costiero di origine vulcanica e da effettuare in barca. Per ogni itinerario sono stati scelti sei geomorfositi o gruppi di geomorfositi, scelti tra i più importanti e con maggiore valenza didattica, e per ognuno di essi è stato progettato uno stop, con osservazioni da effettuare a seconda delle situazioni o dalla barca o a terra.
L'itinerario per l'isola di Lipari inizia ad est con lo splendido Castello di Lipari che sorge su un imponente bastione di lava riolitica, prosegue verso nord con le grandi cave di pomice e con la rara spiaggia di Porticello, caratterizzata dalla presenza di ciottoli di lava nera e di pomice bianca, per terminare a sud con i due notevoli pinnacoli lavici di Pietralunga e Pietra Menalda, che si ergono in mezzo al mare.
L'itinerario per l'isola di Stromboli inizia dal molo di Scari, caratterizzato da una spiaggia con sabbia vulcanica completamente nera, scende verso Ginostra, ove si può percorrere a terra un già collaudato sentiero geologico, continua a nord-ovest con l'impressionante Sciara del Fuoco, un paesaggio unico nel Mediterraneo, e termina di fronte allo scenografico "neck" di Strombolicchio, residuo dello smantellamento di un ben più vasto edificio vulcanico.
Viene sottolineata l'esigenza di questa nuova forma di turismo culturale che è il "geoturismo", valido sotto il profilo dello sviluppo sostenibile, basato sulla spiegazione, promozione e conservazione del prezioso, talvolta unico, patrimonio geomorfologico-vulcanologico delle isole Eolie.

Keywords: Geomorphosites, Geo-Tourism, Lipari, Stromboli, Aeolian Islands, Tyrrhenian Sea.

Parole chiave: Geomorfositi, Geoturismo, Lipari, Stromboli, Isole Eolie, Mar Tirreno.

1. INTRODUCTION

The potential for geo-tourism is high all over Sicily, and especially in the Aeolian Islands. As the geological features of these islands are relevant, the whole archipelago was included in the list of UNESCO natural assets, on the grounds that: "*the volcanic landforms of the Aeolian Islands represent classic features in the continuing study of volcanology worldwide*".

The coastal geomorphosites of the Aeolian Islands typically witness the history and dynamics of past and recent volcanic events and geomorphological processes affecting the archipelago. They may be analysed from different perspectives: from landscape description to scientific interpretations, from encouraging interest in geological knowledge to examining the economic role of Geo-tourism initiatives.

The identification and study of coastal geomorphosites from the viewpoint of sustainable tourism is only the first step towards intelligent fruition of the Aeolian archipelago. Geosite assessment, selection and protection criteria should satisfy not only scientific needs but also the need for social fruition. The fundamental parameters of this type of assessment are essentially as follows: scientific value – educational value – rareness – degree of conservation – visibility and accessibility – extra value, also considering naturalistic, archaeological etc. aspects (Arnoldus-Huyzendveld *et al*., 1995; Panizza & Piacente, 2002; D'Andrea *et al*., 2003; Massoli-Novelli, 2003a; 2003b).

Organising geological and geomorphological excursions allows various advantages, such as promoting the knowledge of Earth Sciences, which is so poorly appreciated among the population at large. This would offer new professional opportunities to young geologists and naturalists and result in a better distribution of tourists: not only in the months of July and August but also in the spring and autumn. In this way the Aeolian territory would benefit from a renewed socio-economic balance, which has long been sought after by local Administrations.

Taking into account the high scientific and educational value of the coastal scenery in Lipari and Stromboli, two geo-tourism itineraries by boat are planned. Six coastal geomorphosites or groups of geomorphosites are individuated for each itinerary. They were analysed through a their detailed geomorphological survey integrated with information provided by scientific and historical literature.

The aim of these two geological itineraries is to explain to tourists visiting the Aeolian Islands every year, that the input of energy into a coastal system via waves is one of the main forces determining coastal processes and how the coast-forming volcanic materials of Lipari and Stromboli act in response to mechanical wave erosion and mass movement processes. Besides, it is important to investigate how the tourism fruition of present coastal scenery can be developed in presence of a high value of vulnerability induced by human activity and, above all, to volcanic hazards consequences.

2. GENERAL GEOLOGICAL SETTING

The Aeolian Islands are located in the south-eastern Tyrrhenian Sea facing the northern coast of Sicily (Fig. 1). They provide an outstanding record of volcanic island-building and destruction processes and ongoing volcanic phenomena. Studied since at least the 18th century, these islands have permitted to investigate on two types of eruption (Vulcanian and Strombolian) and so have featured prominently in the education of all geoscientists for over 200 years.

The archipelago of the Aeolian Islands is made up of seven main islands (Lipari, Vulcano, Panarea, Stromboli, Salina, Filicudi ed Alicudi) and several seamounts and islets, along the internal margin of the Apennine -Maghrebian chain. It is correlated to the complex geodynamic situation of the Mediterranean area which has been site of the collision between the African and Eurasian plates, with a trending convergence (Barberi *et al*., 1974).

The Aeolian Islands are the part emerged of a large submarine volcanic basement extending for around 200 km, having a typical arc-shaped structure. The depth of the basement from which the seven islands emerge ranges from 1000 and the 2000 m b.s.l. They consist mainly of volcanic products, spanning in age from about 400 ka to the Present, and subordinately from Late-Quaternary marine deposits. Vertical crustal movements of the volcanic edifices have been interpreted as being the result of interaction between episodic eruptive events and neo-tectonic processes, both transitory and active on a local scale (Calanchi *et al*., 1996; 2002).

Seismic and volcanic activities linked to Quaternary tectonics and marine erosion, both Pleistocene-Holocene and Present, are the main factors responsible for the great coastal diversity of the Aeolian Islands, both emerged and submerged (Romagnoli *et al*., 1993).

The volcanic coastal landscape of Aeolian Islands is particularly suitable for physical processes (e.g. mechanical wave erosion, mass movement and longshore sediment transport). These processes have played an important role in the development of present coastal scenery with formation of a great diversity of coastal features (e.g. plunging and composite cliffs, embayed and pocket beaches, sea arches and caves, islets and stacks, etc.). All these coastal features develop chiefly along the structural weaknesses (e.g. the joints and the fault planes) or as the result of a differential erosion of dykes. Instead, other marine processes, such as bioerosion and chemical and salt weathering, are absent or insignificant.

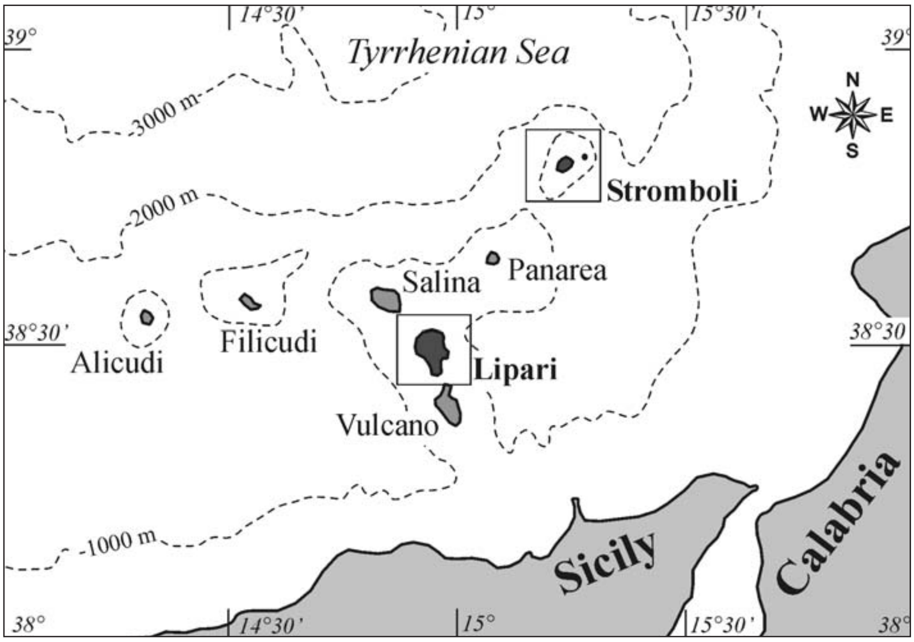


Fig. 1 - Location of the Isles of Lipari and Stromboli in the Aeolian archipelago (South-eastern Tyrrhenian Sea).

Inquadramento geografico delle Isole di Lipari e Stromboli nell'arcipelago Eoliano (Mar Tirreno sudorientale).

3. THE ISLE OF LIPARI

3.1. Geological framework

Lipari is the largest island of the archipelago with a surface extending for 38 km^2, a maximum length of about 9.5 km (north-south) and a width of 7 Km (east-west). During the Neolithic Age it was one of the rare sources of obsidian in the Mediterranean and it was also famous as the most important trading station for kaolin and pumice.

From a geological and volcanic viewpoint, the isle of Lipari – like Stromboli - is the emerged part of a large volcanic edifice, rising from the sea floor at a depth of about 1000 m b.s.l.. Although the geological evolution of Lipari is complex, it can be divided in two phases of different volcanic activity, separated by a long period of dormancy (about 45,000 years), revealed by evident subaerial and marine erosional surfaces.

The volcanic activity of the first period (Paleolipari) starts about 230,000 years BP with the emission of products composed of basalt and andesite. Post-erosional volcanic activity begins at about 42,000 years BP, with very different eruptive styles and magma composition, as testified by the emission of evolved magmatic products (rhyolite – obsidian lava flows) and large amounts of surge deposits (pumice deposits). The last volcanic activity in Lipari occurred between 16,800 and 1,400 years BP and is located in its north-eastern sector. This important activity results in a substantial emission of pumice surge deposits on Monte Pilato and of exceptional obsidian and rhyolite lava flows in Rocche Rosse (Pichler, 1980; Tranne *et al.*, 2000). Recent dating establishes that the last eruption took place about 1400 years BP, covering the fourth and fifth century Roman remains in the Acropolis of Lipari with a thin layer of pumice (Calanchi *et al*., 1996; Tranne *et al.*, 2000).

The coastal scenery of Lipari is varied and rugged; it is characterised by the presence of headland-embayment sequences with numerous sea-stacks, arches and caves. Embayed beaches with sands, gravel and cobbles are principally prevalent along the eastern and northern side of the island, from the port of Lipari to the headland of Punta del Legno Nero. High and steep, plunging and composite cliffs dominate along the western and southern coast; although boulder beaches are present on the south-western coast between Punta Le Grotticelle and Punta Crepazza, and a very sorted sandy beach, nourished naturally by the adjacent landslide and detrital deposits, is embayed in the Valle Muria Bay. In addition, mechanical wave erosion and mass movement are the dominant exogenetic processes along the coast of Lipari (Fig. 2).

3.2. Coastal geomorphosites and geo-tourism

There are numerous pathways on the isle of Lipari connecting various localities but some of these tracks are quite difficult to follow, so it is more interesting to explore the extraordinary coastal scenery of Lipari sailing around the island by boat (Fig. 2).

A complete tour around the island, taking about 9 hours and including two stops at Porticello and Valle Muria beaches, is proposed. It is better to sail round the island anticlockwise, so as to have a good view of the eastern side during the morning and the western side during the afternoon with a spectacular panoramic view of its southern side at sunset. In this way the following coastal geomorphosites of volcanic origin can be observed very well:

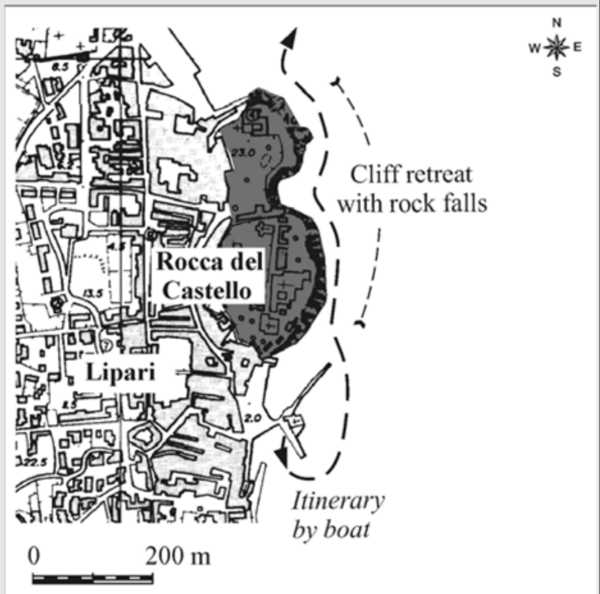
Stop n. 1 – Rocca del Castello cliff

The famous Castle of Lipari is built on a strongly eroded rhyolitic lava dome, linked to the eruptive centre of Monte Guardia (some 20,000 years BP). At the base of cliff, evidences of progressive rock falls can be observed, which have brought the margin of the cliff up to the castle's ancient Spanish walls. Next to the rocky cliff, the interaction between endogenetic volcanic phase and exogenetic processes (e.g. mechanical wave erosion and mass movement) can be observed, together with evidence of human activities and works carried out to protect ancient buildings (Table 1).

Tab. 1 - Dominant landform and processes, vulnerability and accessibility of the first stop selected around the coast of the island of Lipari.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del primo stop selezionato intorno alla costa dell'isola di Lipari.

Lipari geological route - stop n. 1



Main coastal geomorphosite	***Rocca del Castello* cliff**
Position along the coastline and accessibility	East side by boat
Dominant coastal landform	High rocky cliff
Dominant endogenetic process	Rhyolite lava dome
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	Medium (Cliff retreat and rock falls)
Level of Vulnerability induced by human activity	High (presence of tourism activities)

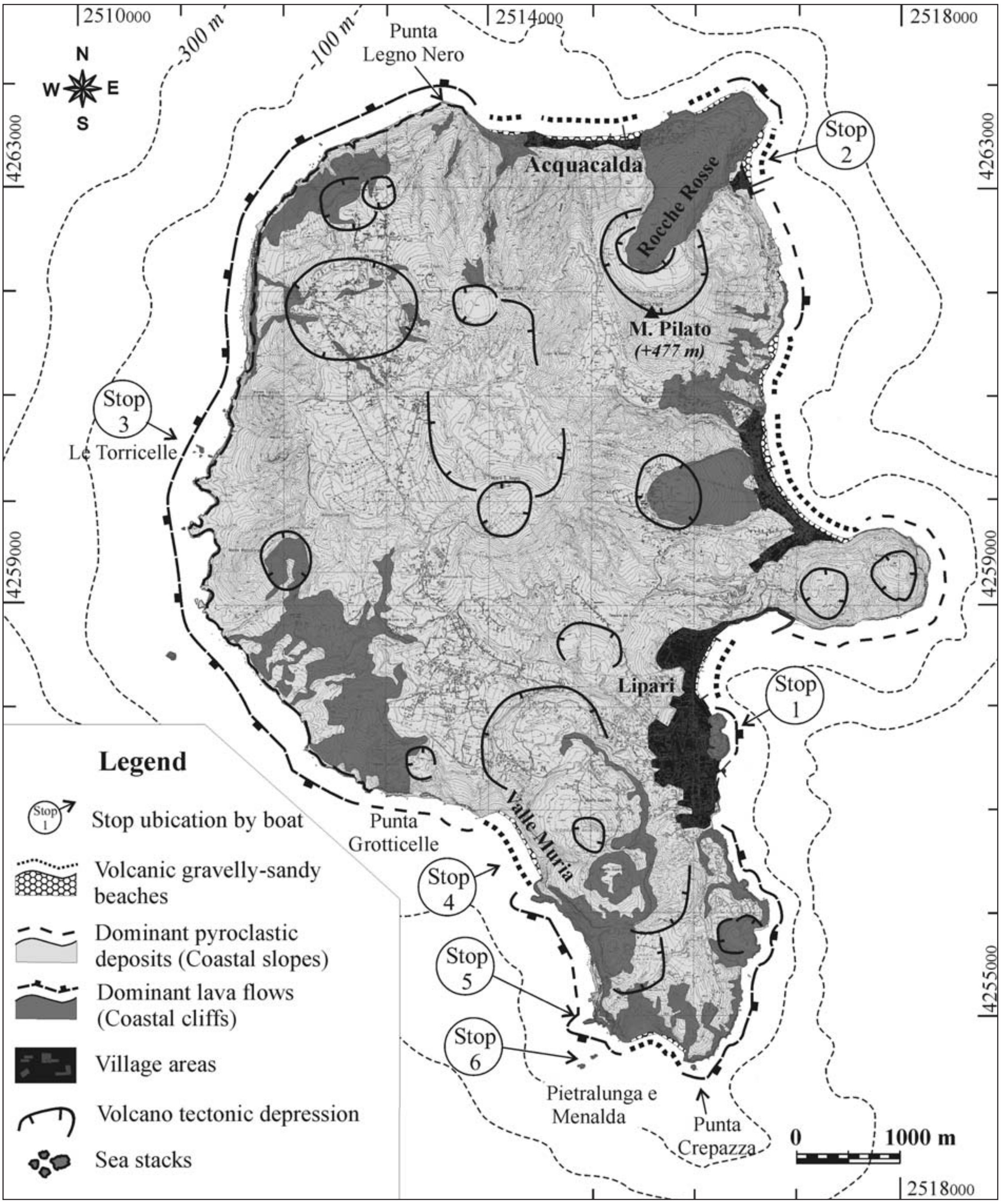


Fig. 2 - The geological-tourism itinerary around the Isle of Lipari. Location, dominant landforms and processes of the main coastal geomorphosites.

L'itinerario geologico-turistico intorno all'Isola di Lipari. Ubicazione, morfologia e processi dominanti dei principali geomorfositi costieri.

Stop n. 2 – Campo Bianco pumice quarry and Porticello beach

The Porticello beach is characterised by the presence of berms with dark volcanic gravels and pebbles and bigger, roundish, light-coloured pebbles of pumice (Table 2). At North of Porticello beach the rhyolite-obsidian lava flow of Rocche Rosse (1,400 years BP) shows spectacular convoluted flow foliation structures visible along the abandoned cliff. To the south on the eastern side of Monte Pilato there is the very large Campo Bianco pumice quarry which has long quays on the coast, where the extracted rock is loaded onto ships (Fig. 3). In the past the discarded materials from the pumice quarry formed a completely white gravelly beach, much appreciated by tourists; at present the pumice extraction is incompatible with a sustainable development of the island.

Stop n. 3 – Le Torricelle sea stack

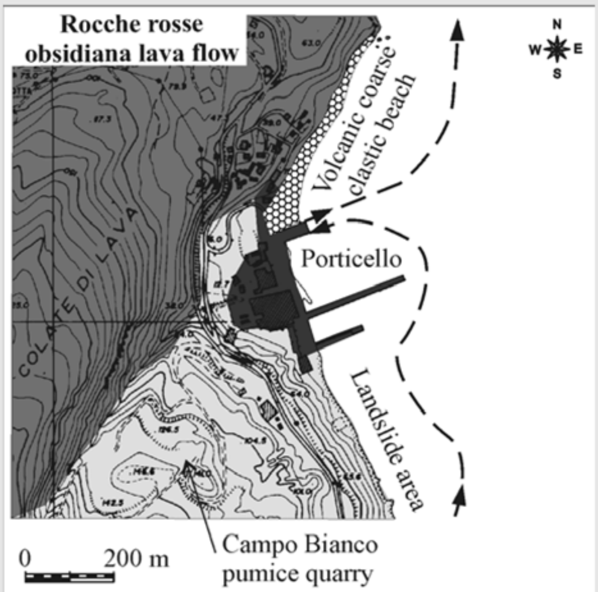
The sea stack of Le Torricelle, some 32 m high, is an interesting coastal geomorphosite, characterised by plunging cliffs with a pillar-like structure originated by effusive activity of Paleolipari volcanic centres (223,000 - 150,000 years BP) and covered by conglomerate levels with pebbles and pyroclastic deposits. Its upper

Fig. 3 - Lipari, stop n. 2. The large pumice quarry at Campo Bianco.
Lipari, stop n. 2. L'estesa cava di pomice di Campo Bianco.

Tab. 2 - Dominant landform and processes, vulnerability and accessibility of the second stop selected around the coast of the island of Lipari.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del secondo stop selezionato intorno alla costa dell'isola di Lipari.

Lipari geological route - stop n. 2

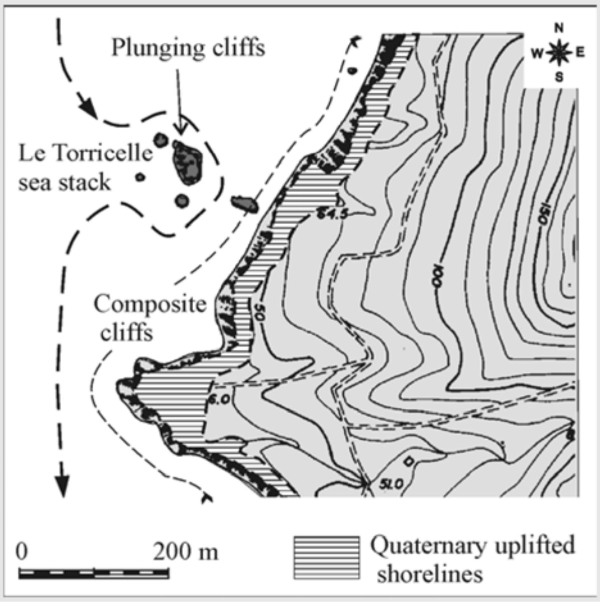


Main coastal geomorphosites	- ***Campo Bianco*** **pumice quarry** - ***Porticello*** **beach with abandoned cliff**
Position along the coastline and accessibility	North-East side by easy foot-path on the beach
Dominant coastal landform	Coastal slope, coarse clastic beach and cliff
Dominant endogenetic process	- Pumice cone with rhyolitic lapilli tuffs - Obsidian lava flow structures
Dominant exogenetic process	- Mass movement - Longshore sediment transport
Level of Vulnerability to natural hazards	Medium (Landslides and shoreline erosion)
Level of Vulnerability induced by human activity	Very high (presence of pumice quarry)

Tab. 3 - Dominant landform and processes, vulnerability and accessibility of the third stop selected around the coast of the island of Lipari.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del terzo stop selezionato intorno alla costa dell'isola di Lipari.

Lipari geological route - stop n. 3



Main coastal geomorphosites	- ***Le Torricelle*** **Sea stack** - **Raised ancient marine deposits**
Position along the coastline and accessibility	North-West side by boat
Dominant coastal landform	Sea stacks with plunging cliffs
Dominant endogenetic process	- Basaltic-andesite lava flow structure - Raised marine deposits
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	Medium (Cliff retreat and rock falls)
Level of Vulnerability induced by human activity	Very low (only presence of sailing tourism)

extremity appears flattened by sea abrasion and is to be linked to elevated marine terraces recognised along the western coast of Lipari (Table 3). The ancient uplifted shorelines are the result of interaction between sea-level fluctuations in the Late Quaternary and vertical movement of the volcanic island (Calanchi *et al.*, 2002).

Stop n. 4 – Valle Muria Bay

Valle Muria is a narrow and elongated wave-dominated embayed beach confined between the two headlands of and Punta di Levante. Tuff and lapilli tuff (hydromagmatic activity) and scoriae of first period (223,000 - 150,000 years BP) crop out along the promontory of Punta di Ponente; they are locally characterised by fumarole levels, ranging in colour from yellow to white and red (Table 4). At Punta di Levante the remains of an ancient lava dome, belonging to the Punta del Perciato eruptive complex, have been overlaid by a massive brown ash tuff deposit (Brown tuffs) with intercalation of one black coarse ash layer related to the Salina volcanic activity (Tranne *et al*., 2000).

Stop n. 5 – Punta del Perciato headland

The rocky headland of Punta del Perciato is the last evidence of a thick, rhyolitic lava dome, dating from 20,300 – 42,000 years BP. Concentric ramp structures with excellent examples of onion-like flux exfoliation can here be observed. In addition, the site is characterised by the presence of a sea arch with vertical walls; it is a significant indicator that a strong wave action in all two sides of the promontory (Table 5).

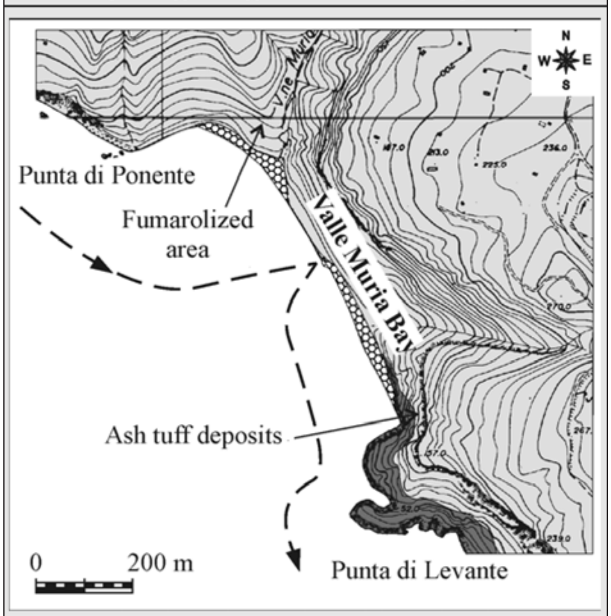
Stop n. 6 – Pietralunga and Pietra Menalda pinnacles

The beautiful Pietralunga and Pietra Menalda pinnacles, some 60 and 25 m high, are the last witnesses of a wide volcanic structure which was dismantled by marine erosion (Fig. 4). They were formed by the same volcanic activity of fourth period (42,000 - 20,300 years BP) which originated the promontory of Punta del Perciato. These two sea stacks are characterised by steeply descending cliffs that pass far below sea level without any shore platform and are attacked continuously by wave erosion (Table 5).

Tab. 4 - Dominant landform and processes, vulnerability and accessibility of the fourth stop selected around the coast of the island of Lipari.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del quarto stop selezionato intorno alla costa dell'isola di Lipari.

Lipari geological route - stop n. 4



Main coastal geomorphosites	- ***Valle Muria* Bay** - **Brown tuffs at *Punta di Levante*** - **Fumarolized area at *Punta di Ponente***
Position along the coastline and accessibility	South-West side by easy foot-path on the beach
Dominant coastal landform	Headland - embayment sequence
Dominant endogenetic process	- Hydro-magmatic activity - Rhyolite lava dome
Dominant exogenetic process	- Mass movement - Longshore sediment transport
Level of Vulnerability to natural hazards	High (Landslides and rock falls)
Level of Vulnerability induced by human activity	Low (presence of sailing tourism and bathing on the Muria Bay beach)

4. THE ISLE OF STROMBOLI

4.1 – Geological framework

Stromboli is the most active volcano in Europe and is famous worldwide on account of its typical "Strombolian" activity, which consists of ejection of ash, lapilli and lava bombs with rare lava effusions of short duration. Stromboli is also considered an extremely important field laboratory for volcanic hazard assessment. It is the northernmost island of the Aeolian archipelago and covers an area of 12.2 km^2. Stromboli with an elevation of 924 m a.s.l. forms a steep and

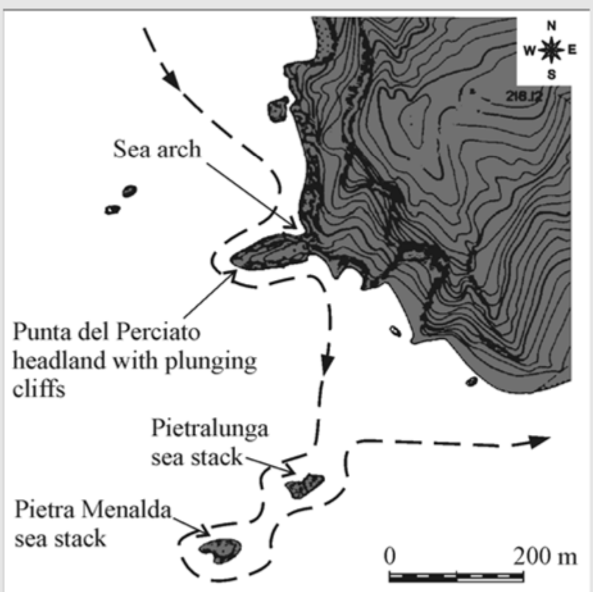
Fig. 4 - Lipari, stop n. 6. The beautiful 60 m high Pietralunga volcanic pinnacle.

Lipari, stop n. 6. L'eccezionale faraglione di Pietralunga, alto 60 metri s.l.m.

Tab. 5 - Dominant landform and processes, vulnerability and accessibility of the fifth and sixth stop selected around the coast of the island of Lipari.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del quinto e sesto stop selezionati intorno alla costa dell'isola di Lipari.

Lipari geological route - stop n. 5-6



Main coastal geomorphosite	- ***Punta del Perciato* headland** - ***Pietralunga* and *Pietra Menalda* pinnacles** - **Sea arch of *Punta del Perciato***
Position along the coastline and accessibility	South side by boat
Dominant coastal landform	Headland with caves, arches and stacks
Dominant endogenetic process	Rhyolite lava dome with concentric ramp structures
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	Medium (Flexural and block toppling and rock falls)
Level of Vulnerability induced by human activity	Very low (only presence of sailing tourism)

uniform volcanic cone which rises from a depth of about 2400 m in the Tyrrhenian Sea.

The island of Stromboli was affected by several collapses, which took place in two main stages: the older one, characterised by three concentric caldera collapses and several pyroclastic eruptions related to a flank collapse toward south-east, and the younger one, characterised by two sector collapses, one flank collapse towards north-west and predominant lava effusions (Pasquarè *et al*., 1993).

The geological evolution of Stromboli is recorded in its subaerial part for a time span from about 100,000 years BP up to the Present. Four major periods (Paleostromboli, Vancori cicles, Neostromboli and Recent Stromboli) have been recognised and further subdivided into 30 volcano-stratigraphic units. Pyroclastites (ignimbrites, surge and lahar deposits) predominate over lavas (latites) during the first two periods, while the more recent products are generally basalts, with shoshonitic composition (Horning-Kjarsgaard *et al*., 1993; Rosi, 1980).

As regards volcanic hazard, Stromboli is at present characterised by a peculiar state of permanent activity consisting of mild intermittent explosions and continuous gas steaming. From time to time this normal activity is interrupted by eruptive crises characterised by either lava emission or more violent explosions. There are on average 2.1 events per year of major explosions with fallout of large blocks and incandescent bombs up to a distance of about 1.5 km from the craters. More violent paroxysms with a larger volume of ejected material and a broader spectrum of phenomena have an occurrence of one event every 10-15 years (Barberi *et al.*, 1993). The island of Stromboli has a high vulnerability to volcanic hazards (e.g. explosive eruption and volcanic landslides) and large tsunamis could also take place as the effect of huge landslide at "Sciara del Fuoco" (Tinti *et al*., 1999).

The morphology of this island is rugged and jagged, owing to continuous volcanic eruptions and marine erosional processes. Flat areas, made up of emerged marine terraces, are very rare. They are site of the two main human settlements: the villages of Stromboli in the north-east side and of Ginostra in the south-west side. The coastal scenery is characterised by the presence of cliffs with more or less gentle slopes. Only on the north-east side the coastal slope is gentle and grass-covered with rich soil and fields under cultivation. Some sandy and pebbly beaches are also found, mainly along the north-east side. A dark-coloured sandy foreland, between Scari and Punta Lena, extends out from the coast towards the islet of Strombolicchio. It is a significant indicator that two dominant swells are in opposition (Fig. 5).

4.2 – Coastal geomorphosites and geo-tourism

Stromboli is an island at high volcanic risk, where it is no longer possible to walk along high-altitude footpaths without an authorised guide. It is, therefore, advisable to explore its rugged coastal landscape by sailing along it, thus reaching also the islet of Strombolicchio, some 1.3 miles away from Stromboli's north-eastern coast.

The complete tour by boat around the island takes about 5 hours, including a stop at the village of Ginostra (Fig. 5). Starting from the pier of Scari and proceeding clockwise, the most important coastal geomorphosites of volcanic origin are as follows:

Stop n. 1 – Le Schicciole Valley

Along the eastern coast, three steep small valleys filled with pyroclastic material can be seen. These are volcano-tectonic collapse structures, named "Le Schicciole" and formed some thousands of years ago along the western flanks of Stromboli volcano. They are similar on a smaller scale to the famous "Sciara del

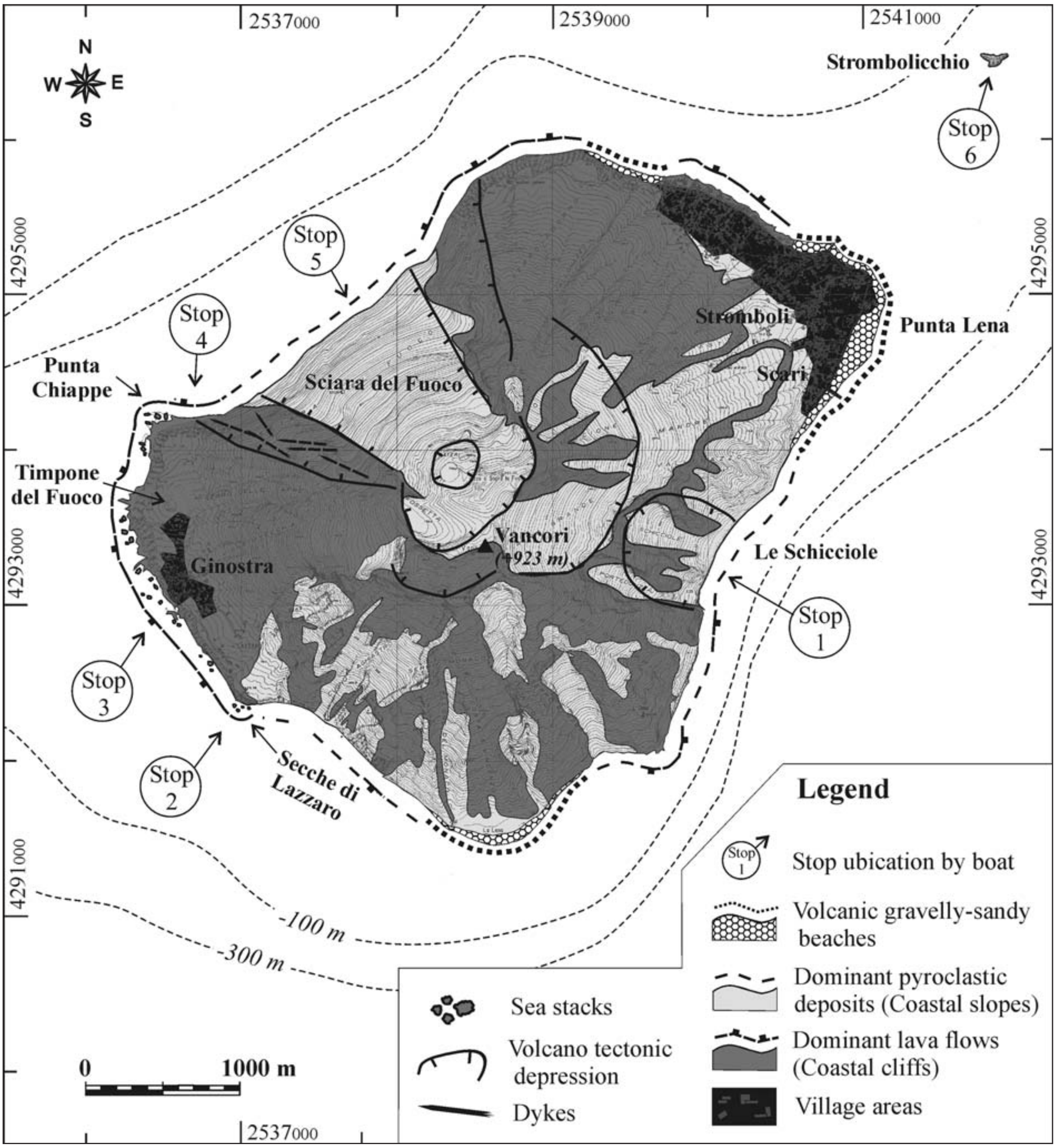


Fig. 5 - The geological-tourism itinerary around the Isle of Stromboli. Location, dominant landforms and processes of the main coastal geomorphosites.

L'itinerario geologico-turistico intorno all'Isola di Stromboli. Ubicazione, morfologia e processi dominanti dei principali geomorfositi costieri.

Fuoco" depression, which will be described in one of the next stops. In fact, also in this case, the hollow spaces left after collapse were later filled by soft and cohesionless pyroclastic materials with respect to the harder, ancient flows which form a sort of container (Table 6).

Stop n. 2 – Secche di Lazzaro underwater arches

In the area surrounding Secche di Lazzaro the coast has an exposure between 90° and 120°N and is still sheltered from the strong north-westerly mistral wind. Since sea dismantling activity is less intense, the "Lazzaro pyroclastites" (some 4,000 years BP) crop out on top of the Neostromboli lava flows (some 14,000 years BP). Here there are, therefore, excellent conditions for observing the various degrees of incidence of erosional processes on the lavas and dip-downstream pyroclastic deposits. Nearby, at Secche di Lazzaro, snorkelling allows the viewing of magnificent rock arches, appearing a few meters below the sea surface. These structures were carved into pyroclastic deposits by wave-motion when the sea level was lower than it is now (Table 7).

Stop n. 3 – Ginostra - Secche di Lazzaro (first "geological-historical path" of the Aeolian Islands)

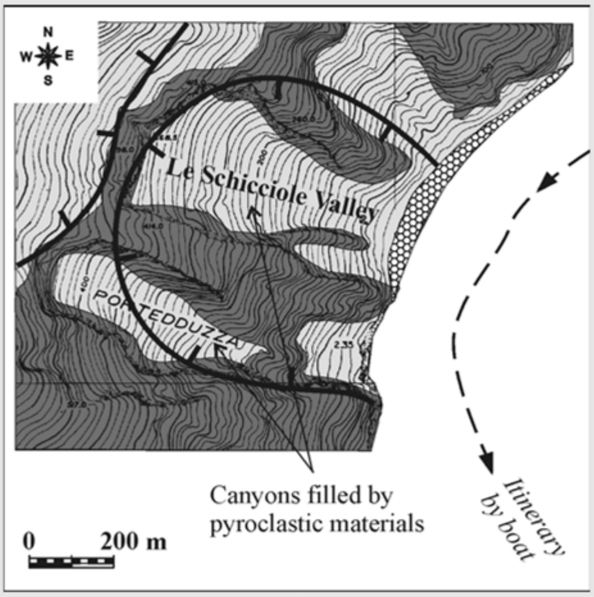
Ginostra is a small coastal village naturally isolated from the lava flows of the ever-active Stromboli volcano. The village is made up of a cluster of very basic, simple houses, still with no running water or electricity. Owing to the high landslide susceptibility of the volcano's flanks, there are no road connections, not even footpaths, between the villages of Ginostra and Stromboli. The passengers arriving by ferryboat from Naples, Messina and the other Aeolian Islands are transferred into small boats that eventually take them to the "Pertuso", the small natural harbour dug by the sea into the black basalt lava. At present, the construction of a little harbour similar to that of Stromboli is in progress, in order to offer safe conditions to the local population and the numerous summer tourists (Table 7).

Some years ago, the first "geological-historical path" of the Aeolian Islands, from Ginostra to Secche di

Tab. 6 - Dominant landform and processes, vulnerability and accessibility of the first stop selected around the coast of the island of Stromboli.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del primo stop selezionato intorno alla costa dell'isola di Stromboli.

Stromboli geological route - stop n. 1

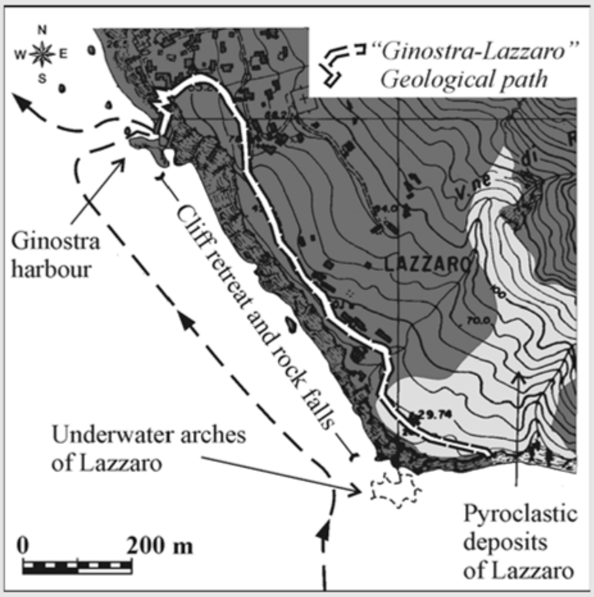


Main coastal geomorphosite	- ***Le Schicciole* Valley** - A variety of volcanic landforms (canyons, landslide areas, etc.)
Position along the coastline and accessibility	East side by boat
Dominant coastal landform	Three steep valleys filled with pyroclastic material
Dominant endogenetic process	Volcano-tectonic collapse structure
Dominant exogenetic process	- Mass movement
Level of Vulnerability to natural hazards	Medium (Volcanic landslide and landslips)
Level of Vulnerability induced by human activity	Very low (only presence of sailing tourism)

Tab. 7 - Dominant landform and processes, vulnerability and accessibility of the second and third stop selected around the coast of the island of Stromboli.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del secondo e terzo stop selezionato intorno alla costa dell'isola di Stromboli.

Stromboli geological route - stop n. 2-3



Main coastal geomorphosite	- ***Ginostra* natural harbour** - ***Secche di Lazzaro* underwater arches** - A variety of volcanic landforms (pahoehoe lavas, etc.)
Position along the coastline and accessibility	South-West side by boat (or snorkelling) and a "Geological - historical path"
Dominant coastal landform	Composite cliffs with underwater arches and sea stacks
Dominant endogenetic process	Lava flow structure and pyroclastic deposits
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	High (Explosive eruption, cliff retreat and rock falls)
Level of Vulnerability induced by human activity	Potentially high (new harbour in project)

Lazzaro, was opened (Fig. 6). It is about 1 km long and its volcanological features of Neostromboli lava flow (13,800 years BP) are particularly interesting: pahoehoe basalt lavas on the path, latitic dykes cutting through it, ignimbrite deposits and their spectacular erosional features, high-energy coastal erosion, with enormous rounded basalt stones and underwater arches carved into pyroclastic rocks (Massoli-Novelli, 1999).

Stop n. 4 – Punta Chiappe dykes

Punta Chiappe is the site where the major volcanological and geomorphological features of Stromboli can be observed better than anywhere else: the vertical lava dykes (latitic in type of Timpone del Fuoco about 6,000 years BP) which radially cut through the main volcanic edifice. Owing to differential erosion, these dykes clearly emerge as brownish walls from the soft and black pyroclastites which surround them. This series of vertical dykes runs along the west flanks of the collapsed structure which gave origin to the "Sciara del Fuoco", described below. At the foothill of the volcano the dykes stretch out into the sea giving rise to a series of small sea stacks, strongly exposed to northern wave activity (Table 8).

Fig. 6 - Stromboli, stop 3. Panoramic viewpoint from south-west of the geological-historical path from Ginostra (left) to Secche di Lazzaro (right).

Stromboli, stop 3. Panoramica da sud-ovest del sentiero geologico-storico da Ginostra (a sinistra) a Secche di Lazzaro (a destra).

Stop n. 5 – Sciara del Fuoco depression

The "Sciara del Fuoco" depression is an exceptional coaxial semicircular escarpment, defined as a large horseshoe-shaped amphitheatre, opened at the north-west end continuing below sea level (Romagnoli *et al.*, 1993). It is located along the western slope of the island where most of the volcano's lava and explosive products are accumulated. This slope is considerably high – some 400 m a.s.l. – with a slope angle of about 35°, and offers an impressive view when observed from a boat.

The "Sciara del Fuoco" is formed as consequence of the youngest flank collapse of Stromboli volcano (Pasquarè *et al.*, 1993) and it is made up of lateral lava flows and cohesionless deposits constantly moving along the slope. These deposits are composed of surge materials, such as scoriae, pumice and volcanic sand, erupted from the volcano's active vents, which are located in a depression called "Fossa" at an altitude of 700 m.

The origin of this concave landform dates from 5-10,000 years ago, following a series of volcano-tectonic collapses (13,800 years BP) which led to the formation of a 2 km long longitudinal depression which continues underwater in a large submarine canyon up to a depth of 1700 m. In its more superficial part, the walls of the canyon are 150-200 m high and decrease progressively until they gradually disappear beyond 1000 m in depth (Romagnoli *et al.*, 1993). The floor of this submarine depression constantly receives the materials erupted by the volcano, offering spectacular views of great interest for geo-tourism as well as for volcanological excursions (Table 8).

Stop n. 6 – Strombolicchio neck

The neck of Strombolicchio (about 49 m a.s.l.) is the only emerged evidence of the earliest evolutional stage (some 200,000 years BP) of Stromboli volcanism. It corresponds to the calcalkaline and andesite-basalt compositional neck of a previous volcanic edifice which was completely dismantled by wave-motion (Calanchi *et al.*, 1996).

Owing to its peculiar structure with steep cliffs and position at some 2 km in direction of north-east from Stromboli, the islet of Strombolicchio, with a powerful lighthouse at the top, has a particular meaning in the social perception of both residents and tourists; consequently, the understanding and promotion of its peculiar volcanological and geomorphological features is of considerable relevance (Table 9).

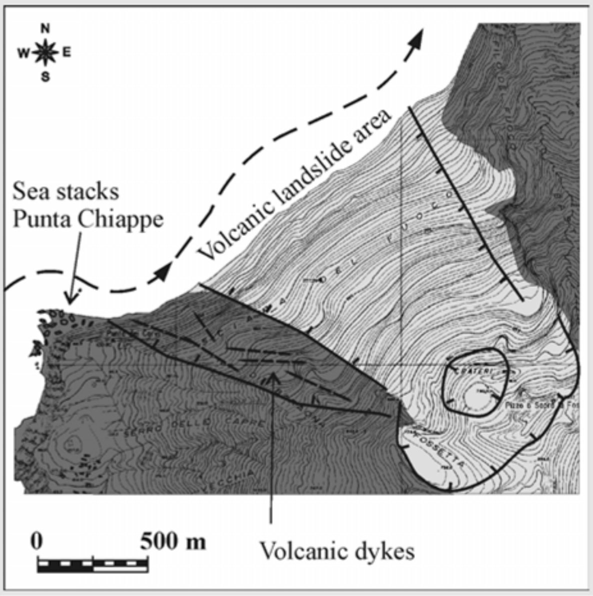
5. CONCLUSIONS

Islands are fragile ecosystems with a very delicate balance between environmental, economic and social activities and requirements. It is widely acknowledged that islands should be areas singled out for priority interventions concerning conservation policies and sustainable development set up by public Boards, in order to better define developing projects and related conservation actions. These goals may be attained by means of properly planned, well-targeted and culturally innovative interventions. Although the classical tourist approach to the Aeolian Islands can offer plenty of enjoyable leisure activities, it may leave the culturally motivated tourist with a sense of bitterness and frustration, resulting from the lack of appropriate structures capable of appraising the numerous and important geological and geomorphological peculiarities of this archipelago. Hence the need to provide visitors with alternative routes which take in the classical tourist destinations of these islands, but also leave plenty of space for the satisfaction of new cultural needs.

Tab. 8 - Dominant landform and processes, vulnerability and accessibility of the fourth and fifth stop selected around the coast of the island of Stromboli.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del quarto e quinto stop selezionato intorno alla costa dell'isola di Stromboli.

Stromboli geological route - stop n. 4-5



Main coastal geomorphosite	- ***Sciara del Fuoco depression*** - ***Punta Chiappe dykes*** - A variety of volcanic landforms (sea stacks, canyons, landslide areas, etc.)
Position along the coastline and accessibility	North-West side by boat
Dominant coastal landform	Canyons and lateral lava flows with pyroclastic deposits, dyke cliffs and sea stacks
Dominant endogenetic process	Volcano-tectonic collapse structure with latitic lava flows
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	Very high (Volcanic landslide, explosive eruption and rock falls)
Level of Vulnerability induced by human activity	Very low (only presence of sailing tourism)

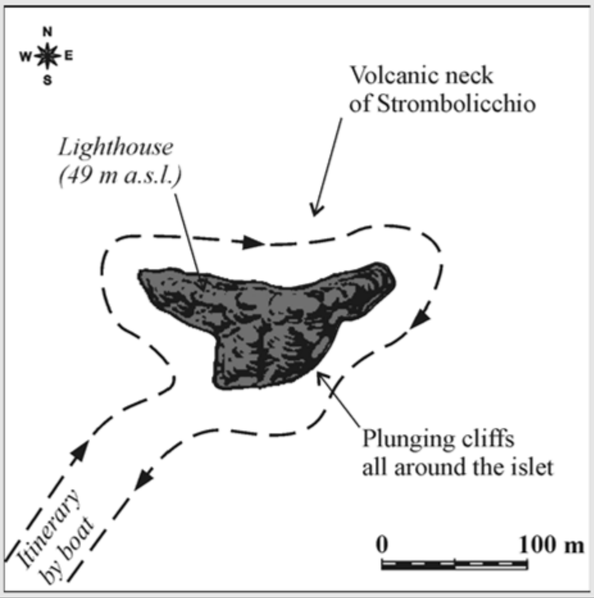
The coastal geomorphosites of Lipari and Stromboli represent a good example of volcanism controlled by marine processes with a high scientific and educational value. The reconstruction of constructive and destructive phases, leading to present coastal scenery, is essential for a systematic knowledge of the archipelago's geomorphosites.

High levels of vulnerability induced by human activity are perceptible in the eastern side of Lipari for the reason that the pumice extraction activity continues and the tourism installations are increasing. Instead, very high levels of vulnerability to natural hazards (e.g. explosive eruption and volcanic landslides) are existing in Stromboli, mainly along the north-west side.

Tab. 9 - Dominant landform and processes, vulnerability and accessibility of the sixth stop selected around the coast of the island of Stromboli.

Morfologia e processi dominanti, vulnerabilità ed accessibilità del sesto stop selezionato intorno alla costa dell'isola di Stromboli.

Stromboli geological route - stop n. 6



Main coastal geomorphosite	***Strombolicchio* neck**
Position along the coastline and accessibility	North-East side by boat
Dominant coastal landform	Islet with plunging cliffs
Dominant endogenetic process	Volcanic neck
Dominant exogenetic process	- Mechanical wave erosion - Mass movement
Level of Vulnerability to natural hazards	Medium (Flexural and block toppling and rock falls)
Level of Vulnerability induced by human activity	Very low (only presence of sailing tourism)

Therefore, according the principles of sustainable development, emphasis is given to the importance of this new form of cultural tourism, named "geo-tourism" finalised not only to promotion and conservation of the coastal landscape of volcanic origin, but also to link opportunities of tourism fruition with the problem of the vulnerability to volcanic hazard consequences.

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