Classification of the Cilento, Vallo Diano and Alburni National Park-European Geopark Coastland

DOMENICO GUIDA¹, ANIELLO ALOIA² & ALESSIO VALENTE³

¹ Department of Civil Engineering, University of Salerno, Fisciano (SA), ITALY, <u>dguida@unisa.it</u>
²Cilento,Vallo Diano and Alburni National Park-European Geopark, ITALY, <u>a.aloia@cilentoediano.it</u>
³ Department of Sciences and Tecnologies, University of Sannio, Benevento, ITALY, <u>valente@unisannio.it</u>

Abstract: In order to address innovative approaches for best conservation practices and sustainable use of marine and coastal geosites, this paper proposes a classification scheme and distinctive evolutionary model for representative carbonate, terrigenous and clastic rocky coast and marine nearshore geosites of the Cilento, Vallo Diano and Alburni National Park-European, based on original analysis and international standards.

Key words: Coastal geosite, rocky coast classification, Cilento European Geopark, Southern Italy.

1. Introduction

The Cilento European Geopark has one of the most fascinating and appreciated coastlands in the Mediterranean countries and thus contains many coastal and marine geosites.

It is characterized by physical, flora, and fauna diversity, with mild and rainy winters and hot, dry and prolonged summers. The historical human occupation in the last millennia has created a very attractive scenery and, locally, a unique cultural landscape (Fig. 1), constituting one of the major social-economic factor in the Geopark. In the last decades, the Geopark coastland has suffered an increasing human pressure due to civil settlements as well as tourist infrastructures, resulting in a hazard for humans, in damaged habitats and in losses for the landscape heritage (Fig. 2). In addition, Global (Climate) Change and related level sea variation induce further disturbance in a very large space-time span [1]. All the previous considerations help in a better understanding of the coastal system in order to perform appropriate actions for coast protection, conservation. sustainable mitigation and remediation. In this direction, major efforts have been lavished by scientific and public institutions in researches and interventions on shorelines and beaches erosion remediation, because of their great economic importance in tourism and recreation. Little attention have been given, instead, to the rocky and cliff coast, although their spatial extension, hazardous characters and scenery relevance. Rocky coastlands constitute relevant areas of the network of protected areas, as Marine Reserves and to assess





Figure 1: "Telegraph Cape", a fascinating geosite with an ancient tower on the top, Figure 2: "Palinuro Natural Arch" damaged by rockfall event in 2011

rocky coast landscape characters, natural ecosystem resources and specific hazardous areas become more and more essential to increase studies and researches in rocky coast environment. Following Sunamura [2], a rocky coast may be defined as a coast that is cliffed and yet composed of consolidated material irrespective of its hardness; these shores are thus commonly characterized by cliffs of various types and associated subjacent platforms [3]. Recently, international organizations, for instance, Unesco [4], IUCN Protocol [5] [6] and Council of Europe [7] [8], have shifted their attention and recommendations from a site-based and disciplinary problem approach to worldwide approach (so called "Ecological Approach") at broad scale [9]. In order to define rocky coast as "interacting complex landscape" between physical, biological and human factors at broader scale, the first step should be to assess the basic physical characteristics [10], such as climate, geological and geomorphological units in term of typology together with a hierarchical space-time classification. The paper deals with a preliminary typology and hierarchical classification of the rocky coast in Cilento Geopark coastland, based on the general and more shared classification criteria [2] and localbased experienced applications, within the ICAM protocol [6], overcoming the littoral cell concept and on modelling of local hydrodynamic processes and considering an integrate approaches to assess coastal evolution taking into account space, time and scale [11]. The approaches have been used to provide an analysis of present day setting as a dynamical result of a past and long-term evolution for the selected coastal segments of Geopark. In this paper, rocky coastal cliffs in Geopark, representative of analogous landforms in Southern Italy, are analyzed in order to define their main characters, classification and morpho-evolutionary outlines. The key outputs from this research are: i) Improved understanding of mid-to-long term coastal behaviour; ii) assessment of rocky coast evolution to modelling future scenarios, and supporting regional information and local data to planning and management policies.

2. Geological and geomorphological coastal setting

The outline of the coast of the Cilento Geopark, part of Campania coast, is very complex with long, rectilinear coastal plains, pocket beaches, prolonged headland and sharp cliffs. Small slands and little stacks are also present near-shore and off-shore. According with Cinque and Ascione [12], the coastland in Campania represents the peri-Tyrrhenian sector of the Campano-lucanian Arc in the Southern Apennine Chain. This represents a segment of a larger fold-and-thrust belt built up in Central Tethys between late Cretaceous and Pleistocene, as consequences of interaction between the European and African plates, spreading of the Tyrrhenian oceanic basin and anti-clockwise rotation of the orogenic front [13]. Due to long-time and complex litho-genetic history, tectonosedimentary events and orogenic displacements, several litho-stratigraphic units can be distinguished (Fig. 3).

The Internal Units, Mesozoic to Tertiary aged, [14] [15] are made up at the base prevalently by marly, varicoloured clay, in oceanic plain sedimentary facies, passing above in calcarenites, calcilutites, often cherty, argillites, sandstones and rare conglomerate deposited in a distal turbidite setting. The External Units constitute mainly by carbonate sediments of Mesozoic and Tertiary age which show sedimentary environments going from the shallow water carbonates with back-reef facies to slope and deep water carbonates [16] [17]; they constitute the bedrock of major cliffed rocky coast in the Sorrento Peninsula, as well as in the southern of Cilento. In disconformity on the previous units there are the Neogenic Sinorogenic Units, represented by several terrigenous formations and units referred to Miocene age in turbidite facies, from wild-flysch to submarine fan sedimentary characters. For instance, Cilento Group [18] [15] is one of these units, which is most widespread in the homonymous area and along the corresponding coast. The Quaternary Postorogenic Units include all the continental, transition and marine clastic sediments, deposited after the final emersion of Apennine Chain (Late Pliocene-Early Pleistocene) [17]. They are represented by aeolian, fluvial, piedmont, lacustrine and travertine deposits along the river valleys and coastal plains, but also they form local cliffs in Cilento. Such units can show intercalation of the products of the campanian volcanic activity. The above geological and tectonic setting, induce a prevalent morpho-structural control of the geopark rocky coastland, with rocky cliffs resulting from retreat and replacement of the previous fault scarps and fault-line scarps (Fig. 3), alternating to terraced plains and shorelines Based on tectonical, lithological and morphological characters several geomorfological Coastal Systems [19] can be recognized. Bulgheria Mt., in the southern Cilento Geopark are representative of



Figure 3 - Southern Campania Geological Setting. Legend 1: Quaternary Postorogenic Units; 2: Volcanic Units; 3: Pliocenic clastic deposits; 4: Neogenic Sinorogenic Units; 5: Internal Units; 6: External Units; 7: main faults; 8: low and sandy coastline; 9: high and rocky coastline; 10: eruptive centre.

Carbonate coastal mountainous massifs, with karst summit and bounding high structural mountain slope, locally plunging to the coastline. Terrigenous coastal mountainous massif. almost exclusive of the Cilento Geopark, are characterized by sharpest ridges and deeply incised ravines descending to the sea through denudational and depositional stratified cliffs, locally terraced. Also in Cilento Geopark, but in limited stretch, are distinguishable Marly-clayey hilly coastal cliffs, with rounded ridge and coastal slope locally steep and often landslide evolving. In order to complete this analysis it is not forget the Clastic coastal cliffs, generally with Pleistocene aged beach-dune system, locally cliffed.

3. Coastal classification

Different classifications have been applied to coasts in attempt to characterize dominant features in terms of physical or biological properties, models of evolution, or geographic occurrence. For a comprehensive analysis of coast classification see the papers [19] and [20]. Due to more interdisciplinary studies of coasts and because of the increasing availability of information, especially base maps in digital formats processing in GIS frameworks, integrated and systematic approaches to coastal classification are favoured. A new approach to a comprehensive classification system is thus proposed for the coastal fringe, a swath zone 3 to 10 km wide across the shoreline, which incorporates all important parameters necessary to categorize geomorphic units that can be mapped at meaningful scales. Consideration of coastal geomorphological properties are the theme of approximation toward a modern promising taxonomic system, where morpho-structures are the unifying links, which facilitate transition from one hierarchical level to another [21]. The up-to-date approach employs differentiating criteria for hard rock (automorphic) and soft rock (allomorphic) which are divided by chronological coasts parameters related to the age of littoral landforms. Other levels of primary differentiation include geodynamic and morphoclimatic process zones, relief types (morpho-regions), morphogenetic relief features, relief elements and genetically homogeneous surfaces. Coastal Morpho-types are lower level taxons, which provide examples of marine ingression and regression as well as complex process-forms [21]. Following the Fairbridge approach on the regional aspects of Holocene coastal paleogeography in the United State [22], in the Campania Region can be recognized two basic categories of environmental setting that are of great importance: primarily, the geotectonic province coasts based on the concept of tectonically stable regions and those of tectonically active region, secondarily, the *climatic province*. According to recent hierarchical geomorphological proposals [20] [23] [24], the previous Campania Coastal Systems are included in *tectonically stable* Latium-Campania Geotectonic Coastal Regions and in volcanotectonically active region Vesuvius-Phlaegrean Geotectonic Coastal Regions. The first can be subdivided in two Morpho-structural Coastal Provinces from South to North: Cilento with Sele Plain and Sorrento Peninsula with Campana Plain Coastal Province; the latter in Vesuvius and Phlaegrean Coastal Provinces.



Figure 4: Campania Coastal System

The proposed classification for Cilento Geopark coastland includes the relationship between important tectonic, geological and geomorphological characteristics and the various coastal landscapes, formations/systems and groups of habitat types. The main parameters and criteria applied to EUCC Coastal Typology of Cilento Geopark are:

Predominant substrate in the littoral zone: i) hard rocks: rocks which are extremely resistant to erosion including limestones and dolomite; ii) soft rocks: rocks with a lower resistance to erosion (mostly supplying moderate amounts of clastic and sedimentary material to the littoral zone), including sandstones and calcarenites referred to Mesotertiary age, Pleistocene aeolian and littoral deposits, terraced conglomerate; iii) recent loose sediments, including Holo-Pleistocene alluvial and slope sediments. Slope of the coastal zone in a wider context (from the sublittoral zone up to a kilometre inland, distinguishing: i) high and cliffed coasts (reaching over 100 m above sea level in the first 5 km from high water mark); ii) coastal plains, which usually provide wide areas for the development of sedimentary and aeolian systems. Coastal regime, especially used in sedimentary coastal plains, the rationale of this parameter is that the formation and evolution of coastal landscapes depend on the relative wave impact in the littoral zone and, as consequence, on prevalent and dominant winds

Based on the above three parameters, a resulting Cilento Geopark Coastal Typology of four landscape types has been drown, as shown in Table 1 and mapped (Fig. 5)

Coastal Geotectonic Region	Coastal Morpho-Structural Province	Dominant landscape Coastal Morpho- type	Landscape Coastal Component
		1a. Hard rock, cliff	
Latium-Campania Geotectonic Coastal Region	Cilento Morphostructural Coastal Province (<i>Tectonically stable</i>)	Micro-tidal shore of limestone and karst areas in southern Cilento.	Sea cliffs, rocky shores with caves, stacks and arches, bays and pocket beaches and small estuaries.
		2a. Soft rock, slope	
	Cilento Coastal Morphostructural Province (<i>Tectonically stable</i>)	Micro-tidal shores of terrigenous and marly clayey in northern and western Cilento;	Soft rock and other friable sea cliffs with e.g. shale, sandstone and cemented sand of ancient dunes.
		2a. Soft rock cliff	
	Cilento Coastal Morphostructural Province (<i>Tectonically stable</i>)	Micro-tidal shores of loose and cemented clastic Pleistocene deposits.	Aeolian and tidal calcarenite and sandstone
		3a.Wave-domin. Sediment	
	Cilento Coastal Morphostructural Province (<i>Tectonically stable</i>)	Micro tidal zone, sand beach-dune system with recent loose sediments.	Beach-dune coasts and River estuaries

Table 1 – Cilento Geopark Coastal Typology



Figure 4: Distribution of Coastal Typology in southern Campania: in the southern prevail cliffed coasts (horizontal lines: hard rock; diagonal lines: soft rock); in the Salerno Gulf coastline exclusively dominate sand beach dune system.

References

- Piccazzo M., Brandolini P., Pelfini M. (a cura di), *Clima e rischio geomorfologico in aree turistiche*, Studi regionali e monografici, Pàtron Editore Bologna, 39, 2007.
- [2] Sunamura T., Geomorphology of Rocky Coasts. John Wiley & Sons, Chichester, 1992.
- [3] Griggs G.B., Trenhaile A.S., Coastal cliffs and platforms. In: Carter R.W.G., Woodroffe C.D., (eds.), *Coastal Evolution: Late Quaternary Shoreline Morphodynamics*. Cambridge, Cambridge University Press, 1994, pp. 425–476.
- [4] UNESCO, The Integrated, Strategic Design Plan for the Coastal Ocean Observations Module of the Global Ocean Observations Syst. GOOS Report No. 126. IOC Information document Series No.11B3, 2003.
- [5] UNEP/MAP/PAP, White Paper: Coastal Zone Management in the Mediterranean. Split, Priority Actions Programme, 2001
- [6] UNEP/MAP, Draft protocol on the integrated management of the Mediterranean coastal zones. Nice, 2005.

- [7] Council of Europe/UNEP & Environmental Centre for Nature Conservation, *The Pan-European Biological and Landscape Diversity Strategy*. A vision for Europe's natural heritage, 1996.
- [8] Council of Europe, European Landscape Convention. Florence. European Treaty Series – No 176., 2000.
- [9] Vogiatzakis I.N., Griffiths G.H., Cassar L.F. & Morse S., *Mediterranean Coastal Landscape*. *Management Practices*, *Typology and Sustainability*, Final Report. University of Reading, 2005.
- [10] Guida D., Guida M., Lanzara R., Vallario A., Unità Territoriale di Riferimento per la pianificazione ambientale: esempi a diversa scala nell'area di Monte Bulgheria (Cilento, Campania), *Geologia Tecnica e Ambientale*, 3, 1996, pp. 39-66.
- [11] Hanson H., Aarninkhof S., Capobianco M., Jimenez J.A., Larson M., Nicholls R.J., Plant N.G., Southgate H.N., Steezel H.J., Stive M.J.F., De Viendt, Modelling of coastal evolution on

yearly to decaded time scales. *Journal of Coastal Research*, 20(1), 2004, pp. 790–811.

- [12] Cinque A, Ascione S., Geomorphological evolution and oro-hydrographical characters of the Campania Region. In: Vallario, A., (Ed.), *Geological Environmental of Campania Region*, Liguori, Ed., Naples, 2001.
- [13] Patacca E., Sartori R., Scandone P., Tyrrhenian basin and apenninic arcs: kinematics relations since late Tortonian times. *Memorie della Società. Geologica Italiana*, 45, 1992, pp. 425-451.
- [14] Bonardi G., Amore F.O., Ciampo G., De Capoa P., Miconnet P., Perrone V., Il Complesso Liguride Auct.: stato delle conoscenze e problemi aperti sulla sua evoluzione preappenninica ed i suoi rapporti con l'arco calabro. *Memorie della Società Geologica Italiana*, 41, 1988, pp. 7-35.
- [15] Cammarosano A., Cavuoto G., Danna M., De Capoa P., De Rienzo F., Di Staso A., Giardino S., Martelli L., Nardi G., Sgrosso A., Toccaceli R.M., Valente A., Nuovi dati e nuove interpretazioni sui flysch terrigeni del Cilento (Appennino meridionale, Italy). *Bollettino della Società Geologica Italiana*, 123, 2004, pp. 253-273.
- [16] D'Argenio B., Pescatore T., Scandone P., Structural pattern of the Campania-lucania Apennines, Quaderni de "La Ricerca Scientifica" CNR, n. 90, 1975.
- [17] Mostardini F., Merlini S., Appennino Centro-Meridionale, sezioni geologiche e proposta di modello strutturale. *Memorie della Società Geologica Italiana*, 35, 1986, pp. 177-202.
- [18] Amore F.O., Bonardi G., Ciampo G., De Capoa P., Perrone V., Sgrosso I., Relazioni tra "Flysch interni" e domini appenninici: reinterpretazione delle formazioni di Pollica, San Mauro e Albidona nel quadro della evoluzione inframiocenica delle zone esterne appenniniche. *Memorie della Società Geologica Italiana*, 41, 1988, pp. 285-297.
- [19] De Pippo T., Pennetta M., Terlizzi F., Valente A., Principali tipi di falesia nella Penisola Sorrentina e nell'Isola di Capri: caratteri e lineamenti morfo-evolutivi. *Bollettino della Società Geologica Italiana*, 126, 2, 2007, pp.181-189.
- [20] De Pippo T., Guida D., Valente A., Limongi P., Cartografia geomorfologica costiera in ambiente GIS ai fini della pianificazione territoriale nell'area compresa tra Sapri e Maratea. Atti del Convegno GNRAC "Coste:

Prevenire, Programmare, Pianificare", Maratea, 15-17 maggio 2008, pp. 595-604.

- [21] Finkl C.W., Coastal classification: Systematic approaches to consider in the development of a comprehensive system. *Journal of Coastal Research*, 20(1), 2004, pp.166–213.
- [22] Fairbridge R.W., Holocene marine coastal evolution of the United States, in Fletcher C.H., and Wehmiller J.F., *Quaternary Coasts of the United States*, Society of Sedimentary Geology, Spec. Pub. 48, 1992, pp. 9-20.
- [23] De Pippo T., Guida D., Lanzara V., Siervo V., Valente A., Criteri, metodi e procedure innovative per la redazione di cartografia geomorfologica gerarchica: proposte operative in ambiente GIS. Convegno Nazionale AIGEO, *"Ambiente geomorfologico e Attività dell'uomo: Risorse, Rischi, Impatti*", Torino, 28-30 Marzo 2007, pp. 230-234.
- [24] Guida D., De Pippo T., Cestari A., Siervo V., Valente A., Applications of the hierarchic GISbased geomorphologic mapping system, in Marchetti M. and Soldati M., *The role of geomorphology in Land management*, abstract volume, 3rd AIGEO National Conference, September 13-18 2009, pp. 109-110.