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DRAINAGE NETWORK AND ENERGY RELIEF OF MADEIRA ISLAND (PORTUGAL): PRELIMINARY NOTES

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ABSTRACT
A geomorphological study, integrated with satellite imagery analysis, has been carried out in the Madeira Island to identify the influence of neotectonics on the landscape. Drainage network and energy relief are the main geomorphological indexes used to identify recent uplift. The drainage anomalies and areas of high relief energy, often coincident, are not explainable by means of the local meteoclimatic conditions. Some peculiar anomalies, such as hook-like shapes and torsions of the network, distributed on lineaments that coincides with those detectable from satellite images, indicate a differential direction of central block, symptom of a prevailing tectonics of uplift with a probable horizontal component.

RIASSUNTO
Reticolato idrografico ed energia del rilievo dell'Isola Medeira (Portogallo): note preliminari. *E' stato affrontato uno studio geomorfologico preliminare integrato con analisi di immagini da satellite nell'isola di Madeira per valutare l'influenza della neotettonica sulla morfologia. I principali indicatori per identificare il recente sollevamento si sono rivelati il reticolo idrografico e l'energia del rilievo. Le anomalie del drenaggio e le aree ad alta energia del rilievo sono spesso coincidenti e sembrano non essere condizionate dalle condizioni meteoclimatiche dell'isola e risultano essere in relazione ad alcune lineazioni tettoniche evidenziate nelle immagini da satellite. Tale situazione morfologica indica un sollevamento differenziale del blocco centrale con una probabile componente orizzontale.*

Keywords: Drainage network, Energy relief, Neotectonics, Madeira Island.

Parole chiave: Reticolo di drenaggio, Energia del rilievo, Neotettonica, Madeira

1 INTRODUCTION

A stream channel network analysis has been carried out on the existing cartography available at the 1:50.000 scale (I.G.A. Madeira, cf. table attached). On the basis of the detected patterns, network anomalies, that were not justifiable by means of terrain lithology and structural tectonics, were identified. Concurrently, the map of relief energy was derived so that further morphotectonic information via an integrated analysis could be obtained.

2 GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

Madeira Island is located in the North Atlantic, 900 Km southeast of Lisbon. It has an area of 728 Km^2 and 265000 inhabitants. It is of volcanic origin, Miocene period, and considered as the present location of a hotspot that also originated the Desertas Islands (which belong to the same volcanic complex), Porto Santo Island and the seamounts Seine, Unicorn, Ampere, Coral Patch and Ormond. Madeira has in its central region swarms of vertical dikes, normal faults, graben structures and cinder cones, parallel to the long axes of Madeira (EW) an area characteristic of volcanic rift zones (Biancotti, 2001; Geldmacher & Hoernle, 2000). Lithostratigraphically the geology of Madeira Island can be divided into three units. The first, a basal unit, was formed during the late Miocene to Pliocene and is mainly formed by volcanic breccias and pyroclastic deposits. The second, the middle unit, is composed by basaltic lava flows and formed from the Pliocene to the Pleistocene. The third, the upper unit, consists of scoria cones and intra-canyon lava flows formed during the renewed volcanic stage of evolution of the island (Geldmacher & Hoernle, 2000).

The orography is characterized by a strong relief with altitudes that reach 1860 m, the average altitude is of 700 m. Average rainfall values vary from 600 mm in the southern coast to 3000 mm in the areas of high altitude.

The lithology and the structure of the volcanic body, which originated the island itself, mainly influence the morphology of Madeira Island. Climatic changes, the last periods of quaternary volcanic activity (Mata, 1996), neotectonics and sea level variations have played an important role in the definition of the morphological configuration. In addition, intensive anthropic impacts, essentially concentrated on coastal areas, have caused further changes to the landscape. The most active processes are coastal erosion (the northern shore faces NE and N winds, hence it is affected by active marine ero-

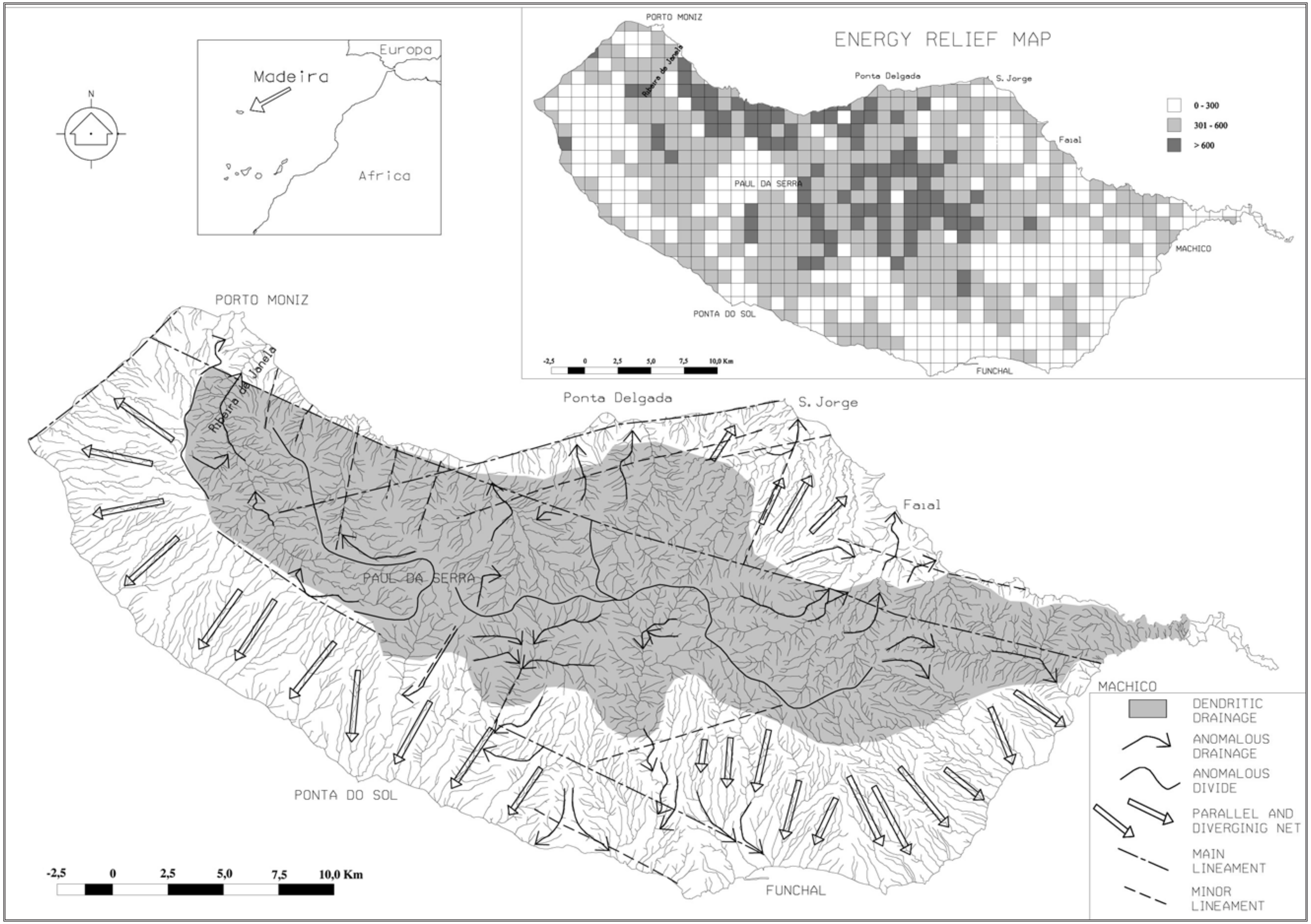

Fig. 1 - Drainage system of Madeira island (I.G.A. Madeira, 1:50.000 modified and reduced). Some network anomalies and main drainage pattern types are highlighted. Energy relief map (top right).

Sistema di drenaggio dell'isola di Madeira (I.G.A. Madeira, 1:50.000 modificata e ridotta). Sono evidenziate alcune anomalie del reticolo e le principali tipologie dei pattern di drenaggio. Carta dell'energia del rilievo (in alto a destra).

sion whereas the southern shore results to be more protected), run off erosion and chemical weathering of pyroclastic lithologies. The drainage network is heavily incised and vertical erosion dominates.

2.1 Drainage network analysis

The study of the drainage network (fig.1) indicates at least 2 main patterns, parallel diverging and dendritic ones, and reveals that generally the existing basins are distributed in a centrifugal manner around the central relief. The Ribera de Janela basin represents an exception; it develops by overlapping in an anomalous way transversally to the dominant drainage direction. It is likely that such a basin represents a more recent formation compared to the surrounding drainage system. A significantly diverging drainage pattern extends in the area south of the main divide, between P.ta do Sol and P.to Moniz (WNW part), in the area between Funchal and Machico (SSE part) and in the area north of the main divide between the Arch of St. Gorge and Faial. Diverging nets are typically derived from previous alluvial fans and/or pediment surfaces (cfr. Nesci & Savelli, 2001). Where it is found, diverging drainage developed independently both from the geological and structural setting and from the age of terrain. Sometimes together with diverging patterns a parallel net prevail, especially in the SW coast sector of the island. Parallel streams in this diverging net could be derived from the ancient topographic configuration on a more pronounced slope. A dendritic-feathered pattern prevails in the central part of the island, it generally develops on rocks of uniform sedimentary units. This pattern shows a very high drainage density. Anthropic modifications affected the channel network around densely populated and intensively cultivated coastal areas.

A detailed analysis has allowed the identification of network branches characterised by an anomalous pattern (torsions, elbow-like, rectilinear and barbed segments). The occurrences of such anomalous branches, that can be correlated to lineaments (Fig.1, Fig.2), have been interpreted as tectonic constraint of the network. In fact, they are not justifiable by other causes (selective erosion, slope gradients, anthropogenic factors, etc.). This is also confirmed by the exceptional correspondence that exists between the majority of the lineaments and those detectable from satellite image interpretation (cf. Fonseca & alii,1998 a and b)

2.2 Relief energy analysis

The relief energy analysis has been conducted by extraction of an energy map. Topographic maps (1:50.000 scale) of the Madeira Island have been divided into 2 by 2 cm. squares (equivalent to a linear scale of 1.000 m on the ground) (cfr. Klein & Antun, 1983). Subsequently the squares have been numbered according to an orthogonal co-ordinate system. For every square minimum and maximum elevation have been estimated using contour lines as references (equidistance equals 25 metres). The relief energy has been obtained by subtracting the minimum from the maximum value. The obtained map presents two areas of high relief energy. One extends essentially on the central region of the island, occupied by the central massif, the other is located in the northern part between P.to Moniz

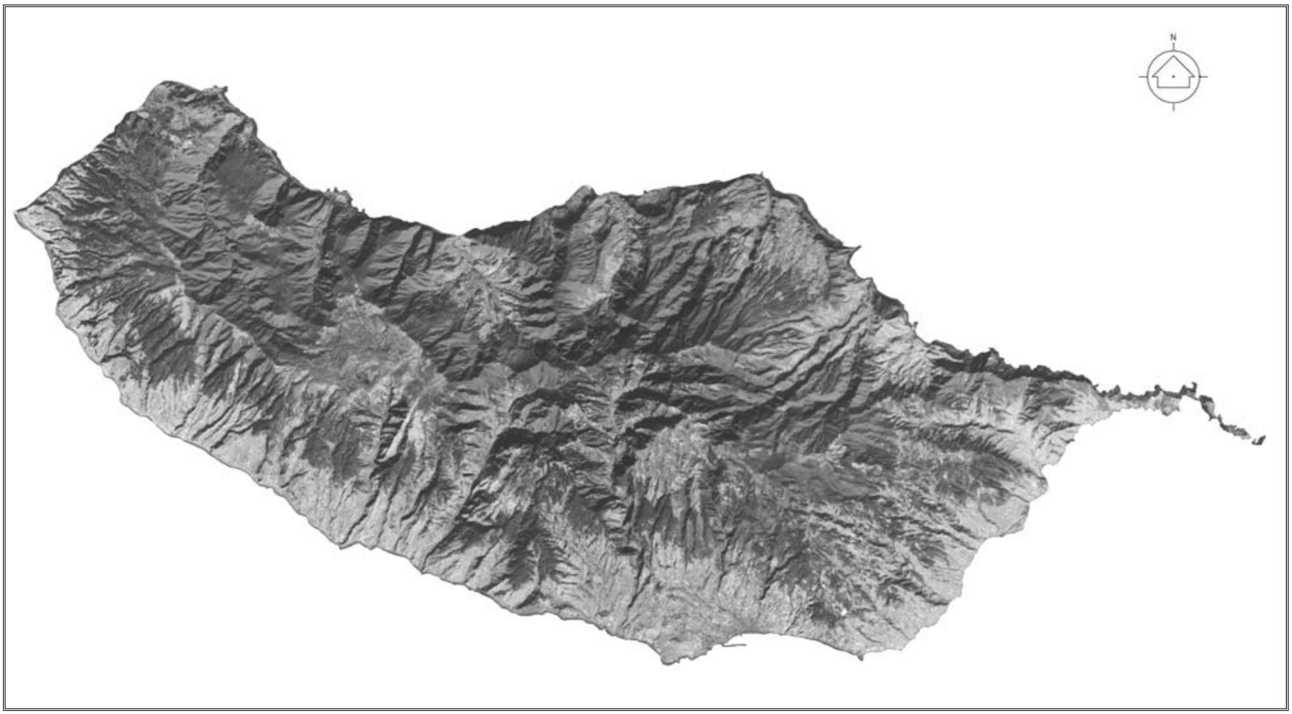

Fig.2 - Spot image of Madeira Island (Project Corine Land Cover Ilha da Madeira.CNIG. Secretaria Regional do Equipamento Social.Governo Regional da Madeira)

Immagine da satellite dell'isola di Madeira (Project Corine Land Cover Il ha da Madeira.CNIG. Secretaria Regional do Equipamento Social.Governo Regional da Madeira) and P.ta Delgata, where values are certainly enhanced by the ongoing erosion due to its peculiar exposition. To highlight the spatial similarities among all high relief energy areas and the high drainage density, all the most significant anomalies of the drainage network are concentrated in these high relief energy areas.

3 CONCLUSIONS

This study aimed at highlighting the presence of some landscape anomalies in specific areas of Madeira Island. These areas are separated by main lineaments that are easily detectable from satellite imagery (fig. 2).

The diverging/parallel pattern, that corresponds to low energy relief zones, indicates the presence of a palaeo-landscape that has been partially reshaped by erosive processes only in the south and north-east parts of the island. When compared to others, these sectors seem to have been subjected to a minor uplift. In contrast, the central part of the island shows a dendritic drainage pattern with high drainage density and many anomalous tracts of the rivers (captures elbows, torsions, barbed rivers, etc.). This generally indicates drainage in evolution. Anomalous trend of the divides shows strong headwater regressive erosion with a clear tendency to hillslope retreats. The high-energy relief is found just in this sector, even though in places (e.g. coastal area) such a situation can result from the high denudation rate of the northerly facing basins. The north-west part of the island is characterised by the anomalous basin of Ribera de Janela river elongated in NWSE direction. The shape of this basin that shows a very low energy relief probably represents the response of this mountain sector to a very recent evolution. This assumption is justified by the anomalous length of the stream when compared to all rivers of the island and by the incomplete erosion of the palaeosurfaces of Plan De Serra, which is most likely, a remnant of ancient landscape. In conclusion, we identify several areas that present a different tectonic behaviour by means of the geomorphological analyses reported above. In particular, the central area appears to be the most affected by dynamics of uplifting whereas lateral areas seem to be substantially stable or however interested by minor uplifting. Torsions of the stream channels in correspondence of the two principal NWSE lineaments, might be due to different horizontal components: clock-wise movements in the southern portion and anti clock-wise movements in the northern one.

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