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IMPLICATIONS OF EXPECTED CLIMATIC CHANGES ON THE ISLAND OF RHODES

GEOGRAPHY AND GEOLOGY OF THE ISLAND OF RHODES

by

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2.1. GEOGRAPHY AND GEOLOGY OF THE ISLAND OF RHODES

2.1.1. Geographical and Geological setting

The island of Rhodes is located at the southeastern region of the Dodecanese group of islands. It is located at the eastern most part of the Hellenic arc, which is extended between Peloponese and Asia Minor and includes the islands of Kythira, Antikythira, Crete, Kassos, Karpathos and Rhodes.

The island of Rhodes (fig 1) has elongated NE-SW oriented shape, with its major axis having a length of 77 km., and width about 37 km. It is situated between 35 52 N and 36 28 N and from 27 40 to 28 16 E and has an areal extend of 1399 km^2 whilst the length of its coastline is about 221 km.

2.1.1.1. Stratigraphy

The rocks which comprise Rhodes island belong to the following three major tectonic units (fig 1): the lower unit, considered to be autochthonous and para-autochthonous, the intermediate allochthonous unit and the upper neoautochthonous unit (Mutti, et al. 1970).

a) The autochthonous and para-autochthonous lower unit includes the rocks of the Attaviros Group and the Kattavia Flysch. In the Attaviros Group we distinguish the Akramitis Limestones and the Kakoskala Marly Limestone. The Akramitis Limestone, with an average thickness of 480 m. and about 800m. in the Attaviros area, consists of thin to medium-bedded gray limestones with scarse chert nodules of Turonian - Middle Eocene age. The Kakoskala Marly Limestone (75 m. thick) consists of marly limestones with chert nodules. In the middle of this unit there is a layer of gray nummulitic limestone with an age of Middle and Late Eocene.

The Kattavia Flysch (1500m thick) lies conformably over the Kakoskala Mariy Limestone, it is of terrigenous origin and has a Middle Eocene age. At Lindos region the flysch appears to be partially metamorphic.

b) The intermediate allochthonous unit consists of three sub-units:

- The lower sub-unit is in direct contact with the Kattavia Flysch and is made up of the Archangelos Group and the Archipolis Flysch. (Mutti et al. 1970). The Archangelos Group is composed mainly, by the Salakos Limestone (700 m thick) which has a Norian to Early Eocenic age. It consists of massive gray limestone, dolomitic limestone and dolomite. The Archipolis Flysch (110 m thick) has its lower part made up of marls, whilst the middle and upper parts are composed of alternating sandstones, conglomerates and marls. An Early Eocene age is attributed to this flysch.

- The upper sub-unit of the allochthonous unit is represented by the Profitis Elias Group which is composed by two formations(Ferrari Aradicini, 1962), the Elaphokampos Cherty Limestone(250 m thick) formed mainly by dolomitic limestones of Liassicage, and the Malona Formation (200 m thick) made up of limestone containing chert nodules, radiolarites, marls and chertylimestones. The age of the latter is from Early Liassic to Senonian. Between the above described allochthonous sub-units there are modest allochtnonous masses of ophiolite composed of gabbrodiabase and serpentinite. An analogous stratigraphic picture is presented by the Kopria Diabase-Radiolarite formation whose age extends form the Jurassic to Early Cretaceous.

- Except these two sub-units, the third sub-unit which belongs to the intermediate allochthon is Lindos Limestone. This sub-unit has an uncertain tectonic position, consists of thick- bedded crystalline limestones and it is about 450 m thick. Within its middle and lower part there are stratigraphic layers containing benthonic foraminifera which may indicate a Cenonian age.

c) The neoautochthonous sedimentary sequence lies in angular unconformity on the autochthonous and allochthonous units. This neoautochthonous unit consists of the Vati Group and the"Levantinian" deposits. The Vati Group (Middle-Late Oligocene to Aquitanian), is present in the central part of the island of Rhodes, whilst in the southern part of the island this group consists of the following formations in ascending order (Mutti et al. 1970):

i) The Koriati Conglomerate (about 115 m thick), represented principally, by a conglomerate consisted of limestone, ophiolite and radiolarite clastics. It has been formed in a fluvial or deltaic depositional environment.

ii) The Dali Ash Flow (about 5 m thick), composed of pyroclastic deposits derived from rhyolitic magma. It is an excellent marker horizon for chronostratigraphic correlation within the Vati Group (Gauthier et al. 1976).

iii) The Messanagros Sandstone-Conglomerate (about 450 m thick), considered to be deposits of marginal turbidites whilst paleo currents indicate a main sediment transport direction from the west. A conglomerate (100 m thick) is present at the base of this formation which was deposited in a fluvial environment and it is made of ophiolite, limestone and radiolaritic rock-fragments. The uppermost part of the Messanagros Sandstone-Conglomerate formation which consists of sandy clay, ophiolitic conglomerate and sandstones, is considered to represent deposits formed at the margin of a deep basin.

As "Levantinian" deposits (Desio, 1931) here are considered all Neogene continental clastic deposits which are present in the island of Rhodes. They lie, in angular unconformity, on top of the Vati Group have a thickness of several hundred metres and are of Pontian age. Their depositional environment is partly fluvial and partly lacustrine. The fluvial member is characterised by gravelly-sandy facies whilst the lacustrine one by marly-sandy facies. At the northwest and eastern coast of the island the"Levantinian" deposits are covered by the transgressive deposits of the Sgourou Formation (170 m thick). The latter lies unconformably on the "Levantinian" deposits which consist of marls, sands and gravels. A layer of fossiliferous calcarenite named "panchina" is often present at the top of the Sgourou Formation. Its age extends from the upper Pliocene to Lower Pleistocene. In the internal parts of Rhodes and on the Levantinian deposits a calcaraeous palaeosoil known as "Poros"(Desio, 1931 , Orobelli 1967), is widely present. It is usually found at the margins of palaeo lakes having a probable age of Lower Pleistocene.

The geological sequence of Rhodes island is completed by the alluvial deposits in the form of terraces,landslide deposits and talus slopescrees.

2.1.1.2. Tectonism

The Geological Structure of the island of Rhodes is characterised by three tectonic systems:

a) a system of tight folds, locally overtuned. The above tectonic structures are present particularly within the Kattavia Flysch and the Attaviros Group having their principal axis direction from NE to SW and a plunge towards SW. This tectonic phase has a Middle Oligocene age, and took place after the deposition of Kattavia Flysch and before the Vati Group transgression. (Mutti et al. 1970). b) a younger tectonic system of folding is superimposed on the previous one formed by a tectonic phase which took place within the Upper Oligocene. It has its main structural trends at a

NW-SW direction and a plunge to the SE (Tournquer, R (1975).c) a system of normal faults cuts all the precious structures and dissects wide portions of the island into horst and graben.Some of these faults are synsedimentary to the "Levantinian"formation while others postdate them.

Finally, the existence of marine terraces raised at different aititudes, indicates recent vertical tectonic movements in the island.

2.1.2. Geomorphology (including deposition-erosion) of the island of Rhodes (fig.2,4).

The island of Rhodes has a smooth relief consisting of hills, hillocks and small mountains (fig 1). This smooth relief is related not only to the lithology of the island, but also, to the existense of a dence drainage network which covers almost the whole island. The drainage line appears to have a NE-SW direction with the numerous torrents and creeks flowing towards all sides of the island and having a predominant drection from SE to NW (Goedicke, 1971). The coastal geomorphology is depented mainly upon the existed lithology. Thus, the areas of Akramiti, Lindos and Profitis Elias, which consist of rocks with relatively higher resistance to the erosional processes, (i.e. ingneous rocks).Limestones and cohesive conglomerates appear to have steep and cohesive coasts and limited littoral deposits. In contrast the rest of the coastline which is made up of easily eroded sedimentary sequences, undergoes and intensive deformation in its geomorphological features (fig 4). Evidences for the above mentioned situation are given not only by the sandy,conglomeritic and gravely deposits which are present alongshore,but also by the existense of a multiform valley system which alters progressively the initial geomorphological picture of the coastal zone, affecting inevitably the configuration of the shoreline (fig 5).

2.1.3. Coastal processes and shoreline stability

The coastal processes and the stability of the shorelines in the island of Rhodes depend upon the lithology and the geotectonic structure of the coastal zone. Furthermore, the shoreline configuration and the topographic slopes alongshore are certainly affected by several external factors such as water flow, wind, sea waves, sea-state, longshore currents etc.

The coastal zone consists of limestones, plutonic and volcanic rocks, flysch, conglomerates "Poros" marls, "Panchina"marine and alluvial deposits (Desio, 1931).

The correlation of the slope topography along the coastiline of the island of Rhodes with the regional lithology and geotectonic structure indicates the presence of three main categories of slopes (Zamani et al. 1979), which are low slopes(0-5 %), intermediate slopes (5-15%), high slopes (15%-20%) and very high slopes (>20 %). The areas of low slopes (0-5%) are extended on Plio-Pleistocene and recent deposist and include the coasts SW of the city of Rhodes and between Lindos and Prassonisi. The rest of the island-coastline is characterised by intermediate topographic slopes (5-15%).

Four geographical regions are characterised by high and very high slopes. These are the area north of Prassonisi Cape at Akramitis, at Lindos and at Profitis Elias. These slopes are observed mainly where the lithology consists of mesozoiclimestones. The high and very high values of the topographic slopes which are present at chalky rocks have been caused by the Quaternary and Neogene tectonism. Certainly the tectonic action continues today to modify the topographic slopes.

Regarding the slope stability of the coastal zone the highest resistance to the external influences (i.e. water flow,land slides, marine activity) is manifested by regions with high and very high topographic slopes due to the existense of limestone otucrops. In contrast the coastal zone with low slopes(0-5%) being formed on Plio-Pleistocene sedimentary sequences of low cohesion is characterised by the presence of unsteady coasts.These coasts are mainly affected by the surficial

water flows induced by the various hydrographic networks, whose presence is not only persistent but also quite extensive (Zamani et al. 1979).

Finally, the geomorphological behaviour of the coastal regions of intermediate slopes (5-15%) could be related to those types of rocks which appear to have either high or low resistanse to erosion .

2.1.4. Evolution of lowlands und subsidence at the island of Rhodes

The lowlands at the island (fig 4) can be divided into two main categories: a) the hinterland lowlands and b) the coastal lowlands:

a) Hinterland lowlands are that of Kattavia region, where over the top of the flysch formation, Holocene sediments of significant thickness have been deposited. These lowlands extend immediately north of Prassonisi Cape and, with a limited extend,at the Malona area. All above lowlands are of Holocenic age,whose formation has been affected not only by tectonism, regional lithology and morphology but also, by the development of numerous hydrographic networks (TOURNOUER, R., 1975).

b) Coastal lowlands exist along the 2/3 of the whole coastline of the island of Rhodes. These are the areas around the city of Rhodes extended up to Salakos town, at the lowland between south of Akramiti Cape up to the west end of Kattavia plain, and the sector which starts from Gennadiou Bay and ends immediately south of Lindos. Other significant lowlands are those which extend from the northern part of Lindos area up to the Malona area, the lowland of Kalithea and the area south of Faliraki.

The width of the coastal lowlands varies between 500 m and 5.000 m (fig 4) and they have developed from extensive valley-systems, which in turn are exclusively formed on easily erodible lithological sequences. A good example is provided at the coastal region at the northern part of the island of Rhodes.There the topographic slopes of the coastal lowlands have values from 2 to 5% in average.

The land-subsidences in Rhodes occur mainly at the NW part of the island and is due to the overload of the submerged regions with sediments derived from the wethering of the surrounding rocks (marls sandstones, not cohesive conglomerates, limestones,Desio et al. 1931). This phenomenon, but to lesser extend,is also present at other areas of the island: for example, at the area north of Lindos and the area between Kalithea and Faliraki. At these areas the land subsidences is caused mainly by the sediment overlond. Undoubtently however tectonism (normal faults) is the maian factor that directs the downward and upward movements, andenhances the occurence of landslides. The role of tectonicm is particularly evident at the coasts of Lindos area, where after the seismic activity of 1926 the limestones were uplifted about 15cm. relatively to the sea-level, as shown by the sea level traces observed there.

2.1.5. Discussion of the climatic implication and suggested action

The transgressions and regressions of the sea are caused by the tectonic movements and by the eustatic changes of the sea-level due to change in the ice volume resulted from different climatological conditions. It has been proved that at the Easter Mediterranean Sea, where Rhodes is placed, about 4000-5000 yr B.P. the sea-level reached its maximum height being from 2 up to 2,5 m higher than that of today. These changes of sea level caused in turn the formation of different sedimentary phases.These events are depicted along the coastal zone of the island of Rhodes, where a recent sedimentary sequence has been deposited in angular contact on older sediments. The former undergoes the intensive wave activity, especially at the NW. S and SE part of the island which leads a new transportation, deposition and sorting of the sediments by the marine processes.

Great part of the coastal and maritime zone is usually consisted of easily eroded soft-rocks and this is causing landslides and landfalls. Measurements have to be taken by constucting sill-divertions dam constructions and other similar proceedings so that the water flow of torrents be reduced or totally confronted. Also the construction of marine structures(i.e. groins, seawalls, breakwaters) at certain areas of touristic interest, seems to be necessary for the protection of the existed sandy beaches from the internsive future wave activity. On the other hand, the reforestation of the bare and burned areas of the island of Rhodes is considered to be indispensable in order to inhibit the sudden flows of the existed torrents and therefore to diminish their catastrophic results upon the coastal zone. The coastal areas of Rhodes island which will be affacted from the sea level changes due to the increase of the temperature in the eastern Mediterranean and Thodes in particular , according to the scenario of the East Anglia group (Guo et al. 1991)are the lowlands depicted in fig 4. These are plain areas of low slope near the sea covered by alluvial deposits in their greatest part.Two such zones exist , one at the north northwestern part and on eat the eastern southeastern part of the island. The north northwestern part consists entirely of alluvial coastal deposits, which have very much been affected by the strong wave action induced by the north nporthwestern winds. On the contrary the lowslope north - northeastern area is heterogenous consisted of Plio-quaternary marls , psammites , sands and gravels. This indicates a minor role of the sorting action of the wind induced waves and currents. It is therefore abvious that the sea level rise in the order of 1m will serously affect all areas with slope between 0%and 5% causing serious to catastrophic impacts on the agricultural and turistic sectors.

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Figure 1 - Hypsometric and bathymetric map of Rhodes island and the surrounding area (in m)

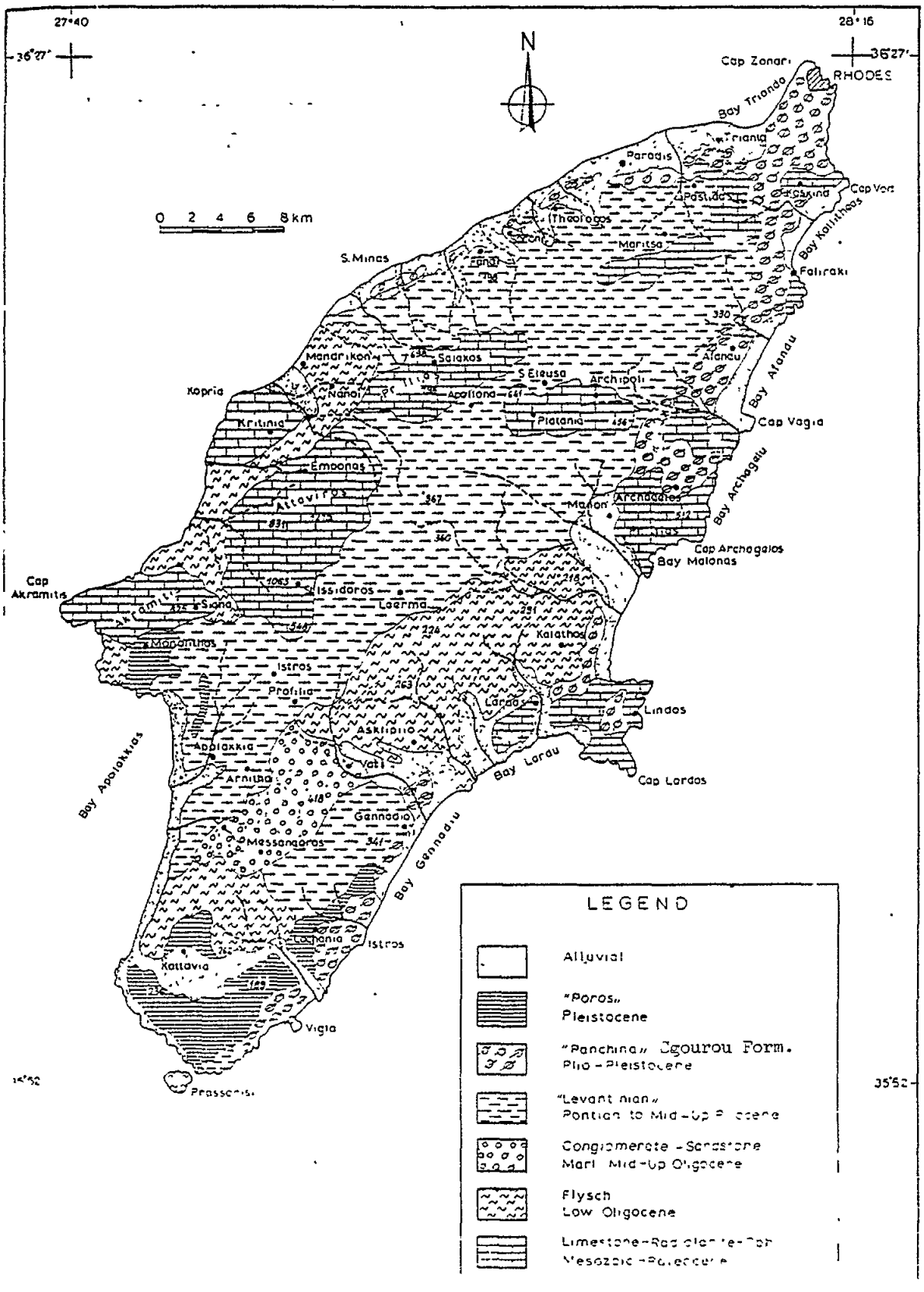

Figure 2 - Geological map of Rhodes island
(Based on various sources combined with personal observations)

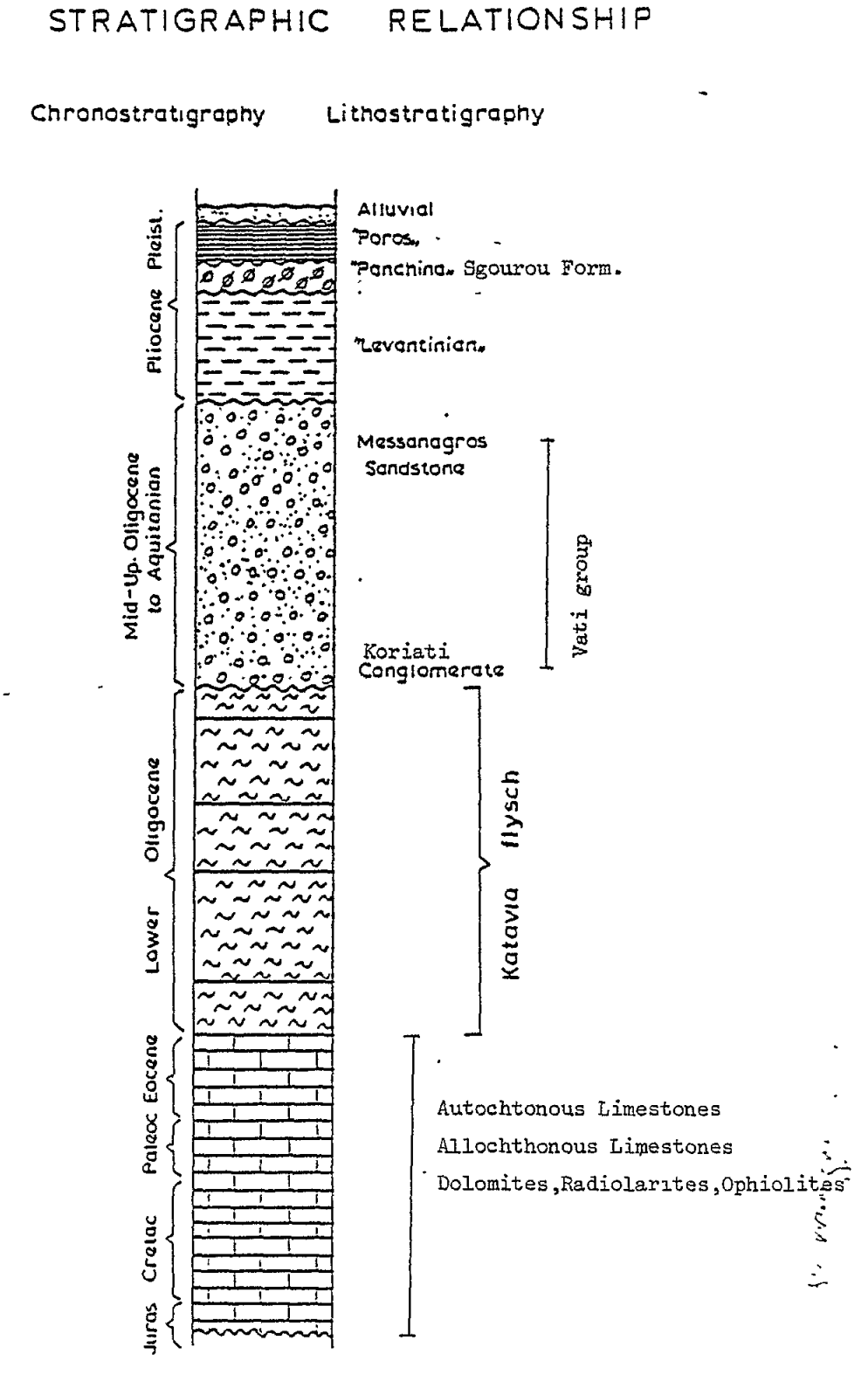

Figure 3 - Stratigraphic column of the rock formations shown at figure 2

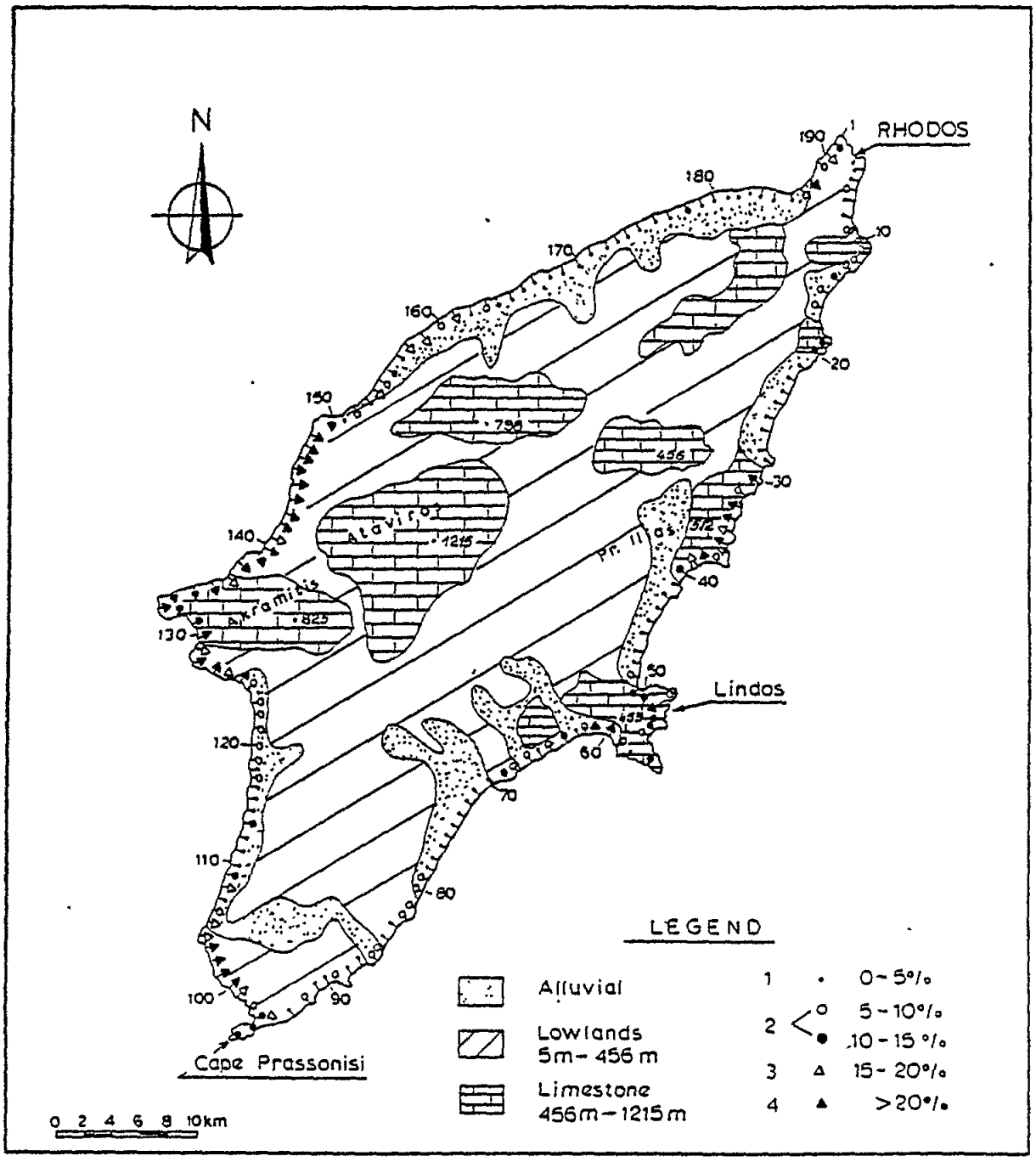

Figure 4 - Geomorphological map of Rhodes island

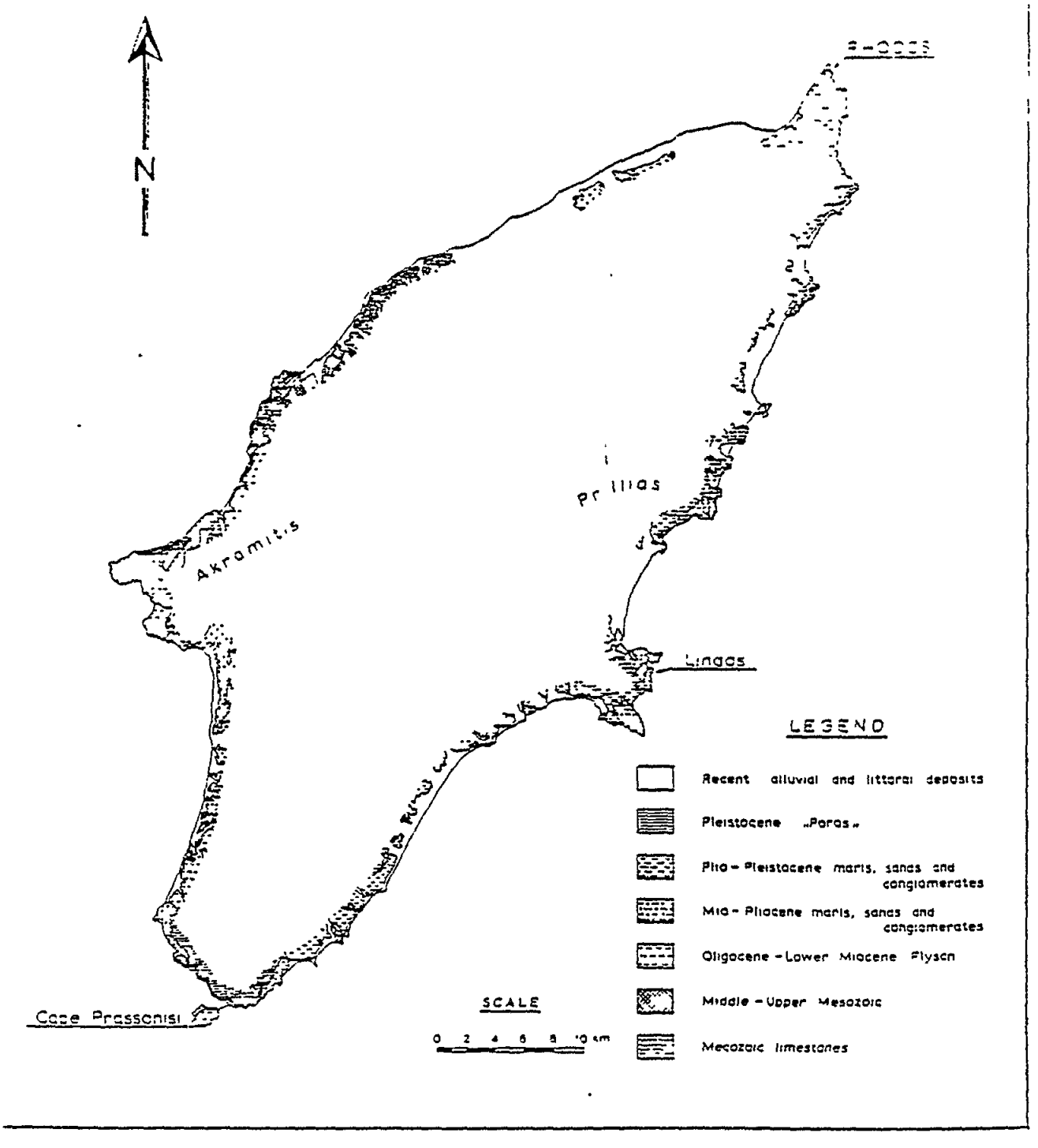

Figure 5 - Geological map of the coastal zone of Rhodes island