INTERNATIONAL ASSOCIATION OF ENGINEERING GEOLOGY

ENGEOL IAEG AIGI ATHENS '97

INTERNATIONAL SYMPOSIUM

ENGINEERING GEOLOGY and the ENVIRONMENT

Engineering Geology Committee of the Geological Society of Greece
(Greek National Group of IAEG)

THE ISLANDS OF THE AEGEAN WORLD

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POST SYMPOSIUM TOUR 3

ATHENS, GREECE, JUNE 23-27, 1997

RHODES ISLAND

Saturday

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JUNE

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HISTORY OF THE ISLAND

Rhodes, one of the Mediterranean's most beautiful islands, lies in the southeastern part of the Greek Archipelago and belongs to the Dodecanese island group. With an area of 1.398 km^2, maximum length of 77 km, greatest breadth of 37 km and a permanent population of about 100.000, is the fourth largest of the Greek islands (**Fig. 1**).

The ancient Greeks were so taken with the charms of the island that they associated its beneficent climate with a myth that has lived on down to our own times. According to this, Helios, the life-giving sun god, enchanted by its natural beauty, asked Zeus as a favour to be the protector and benefactor of the island. In the Mythology, Rhodes was the daughter of Poseidon and Amphitrite or Aphrodite and the beloved of Helios, who gave her name to the island.

According to the historical sources, the first inhabitants must have arrived on Rhodes, as on most of the Aegean islands, 3000 years BC, in the Neolithic period. Around 1550 BC Cretans settled on Rhodes and set up a trading station on its northwestern coast. When the Minoan civilization begun to decline, the Mycenaeans arrived on the island and, first of all, founded Ialysos and Cameiros.

The Mycenaeans were succeeded by the Dorians in 1100 BC, who divided the island into three regions constituting three indepented city-states: Cameiros, Lindos and Ialysos. In 700 BC those three cities, together with Cnidus, Halicarnassus and Cos, formed themselves into an amphictiony (political and religious federation), known as the Dorian Hexapolis.

After the Persian Wars in the early fifth century BC, Diagoras, coming from the aristocratic family of Eratides of Ialysos, won a victory in the Olymbic Games of 464 BC and made Rhodes famous throughout the Greek world.

In 332 BC Rhodians allied themselves to Alexander the Great. After his death, Demetrius from Egypt, one of his succeeders, attacked Rhodes with 40.000 soldiers equipped with the latest technology in siege engines of that time. Rhodes resisted successfully and the Rhodians built a 30 m. high statue dedicated to their patron Helios, the famous "Colossus of Rhodes", one of the "Seven Wonders of the World". Colossus stood in its original position until 227/6 BC, when it was demolished by a strong earthquake. The statue remained fallen but untouched for about 800 years until, in 653 AD, the Moabite Arabs, who had conquered the island, sold its bronze members to a Jewish merchant, who is said to have needed 900 camels to carry it off.

In 164 BC the Rhodians entered into an alliance with the Romans. In 57 AD St. Paul visited the island and in 325 AD Rhodes was represented at the First General Council of the Church. After the division of the Roman Empire the island was incorporated into the East-

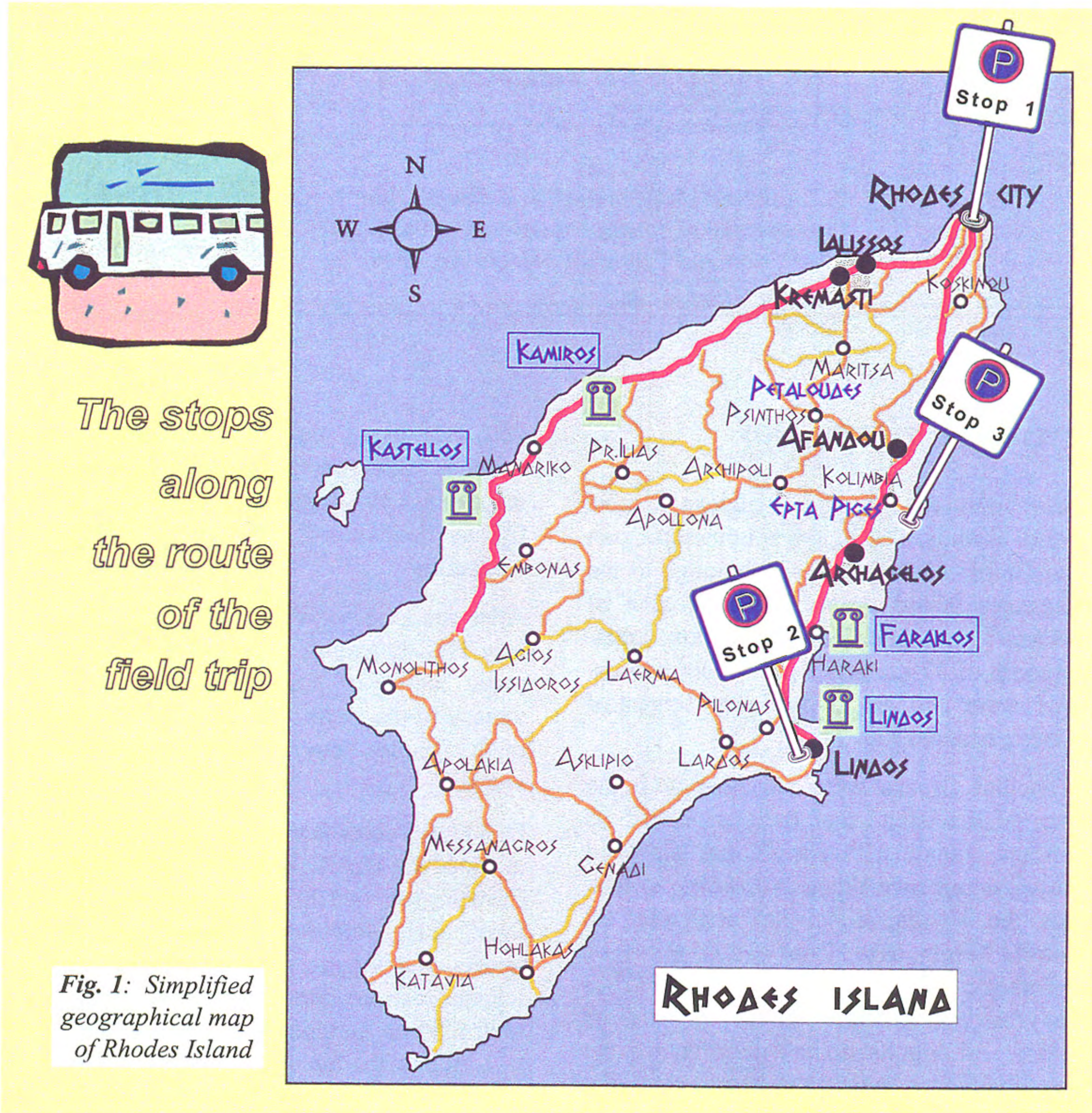

***Fig. 1**: Simplified geographical map of Rhodes Island*

ern Roman State and then to the Byzantine Empire. In 1191 AD, Phillip II of France and Richard the Lionheart stopped off at Rhodes on their way to the Holy Land.

In 1306 AD, Rhodes came under the rule of the Knights of St. John, who played an important role in the struggle against the Muslims in the Holy Land. During that era Rhodes managed to emerged from obscurity and to enter on a new period of prosperity, which terminated on July 22, 1522, when Suleyman II the Magnificent besieged the island with a force of 100.000 men. The Turkish occupation lasted 390 years until the Italians, in 1912, landed forces and took the island. Rhodes, together with all the islands of the Dodecanese were incorporated into Greece on March 7, 1948.

GEOLOGICAL-NEOTECTONIC FRAME OF RHODES ISLAND

The island of Rhodes is located very close to the eastern part of the active Hellenic Arc

(**Fig. 2**), along which a sinistral almost horizontal movement between the underlying African Plate and the overlying Aegean (European) Plate is in progress (McKenzie 1977, Le Pichon & Angelier 1979) and therefore is characterized by strong neotectonic activity and seismicity (Drakopoulos et al 1988, Mariolakos & Papanikolaou 1984, Papazachos & Papazachos 1989).

The high relief of the island, the numerous active faults and fault zones, the deformation of the Pleistocene and Holocene sediments, the vertical displacement of shorelines, as well as the historical reports on destructive earthquakes in the Antiquity and the results of the instrumental seismology in the recent years compose the profile of a very active area in terms of neotectonic and seismicity.

According to historical sources it is concluded that destructive seismic events took place in

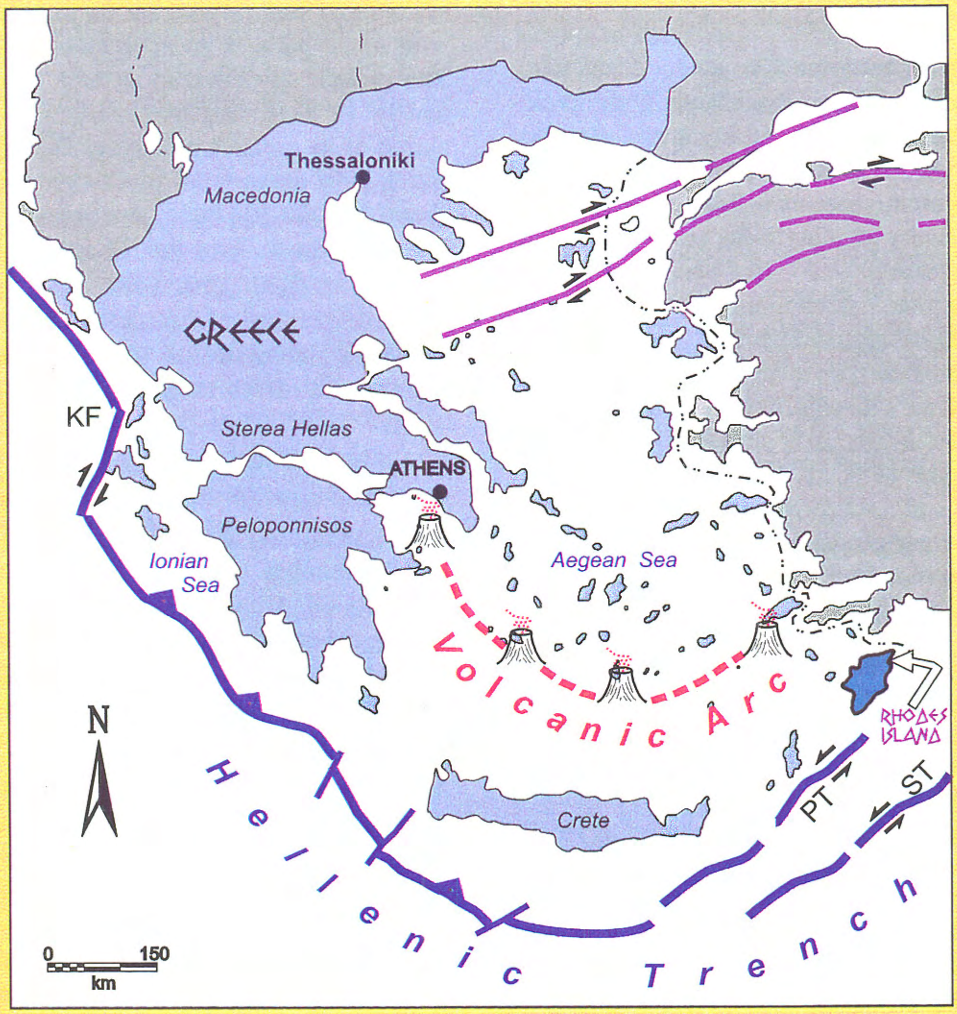

Fig. 2. The modern Hellenic Arc and the geotectonic position of Rhodes Island

227BC, 197BC, 183BC, 344AC, 477AC, 516AC, 1481AC (Papazachos & Papazachou 1989).

The alpine basement of Rhodes island consists of sedimentary, metamorphic and ophiolitic rocks belonging to six alpine units, the most of which are known from Mainland Greece and are the Lindos/Mani unit, the Wild Flysch of Laerma, the Attavyros/Ionian unit, the Archangelos/Tripolis unit, the Profitis Ilias / Pindos unit and the Ophiolitic Nape. Molassic rocks of Oligocene age occur also on the island (Mutti et al 1970, Lekkas et al 1993, Papanikolaou et al 1995).

Four main postalpine Neogene - Pleistocene basins are visible on the island. Their evolution is clearly controlled by major marginal fault zones, dividing the postalpine sediments from the alpine basement. Many of these fault zones, usually trending E-W, are still active up today, creating thus significant large scale morphological discontinuities between the mountainous alpine area and the low relief postalpine area. The most important fault zone of the island with significant dextral strike slip movement trends E-W and is located in the central part of it. It divides the island to a northern and a southern part with many differences in their geotectonic evolution. This fault zone may represent the reactivation of an older alpine feature in the postalpine time.

Numerous active faults and fault zones create a puzzle like structure mainly along the eastern coast of the island, where small, high relief, areas built up by alpine rocks alternate laterally or rise above the younger Plio-Pleistocene sediments (Gauthier 1979, Lekkas et al 1993). The entire island undergoes an eastward rotation around horizontal axis striking NE-SW, parallel to the long axis of the island (Laj et al 1978). Strong evidence of this rotational movement is the asymmetric development of the drainage system of the island and of the superficial distribution of the younger postalpine Plio-Pleistocene sediments.

DESCRIPTION OF THE ITINERARY

STOP 1 THE CITY OF RHODES

History of the City

Ancient Rhodes was founded in 408 BC, as the result of a joint decision taken by the three Dorian city-states of the island - Cameiros, Ialysos and Lindos - to set up a single city in common. It was built on the Hippodamian system and was famous for its town planning with broad parallel and perpendicular streets. The ancient city covered an area of approximately 15 km^2, had five harbors and at the period of its greatest prosperity during the 3rd and the 2nd century BC reached population of about 60.000-100.000. Archaelogical digs have brought to light the Temple of Pythian Apollo, the Stadium and the Theater on Mt. Smith hill as well as foundations of buildings and roads and remains of the underground drainage, the water supply network and parts of the fortification of the ancient city.

In the Byzantine period (4th century AD - 1309) the city of Rhodes was an important naval and military base. To this period belongs a large number of Early Christian churches scattered all over the island and within the city. In the earthquake of 515 AD the city suffered severe damage and shrank to within boundaries much smaller than those of the ancient city.

After the establishment of the Knights of St. John in 1309, the city of Rhodes became the centre of the Order and underwent considerable development. New buildings were put up, the fortifications were strengthened and improved and the city thus took on a medieval Character. The walls which surrounded the city, had a total length of 4 km and had seven gates. The city itself was divided by an inner wall into two parts: the Collachium, where the Palace of the Grand Masters and the administrative centre, and the Chora or Burgo with the residences of the inhabitants and the market.

In 1522 the city was taken by the Turkish hordes of Suleyman the Magnificent and in 1912 by the Italians, who rebuilt the city and put up new buildings around the medieval city.

Geology & Geotechnical Conditions of the City of Rhodes

The city of Rhodes is located in the northeastern part of the postalpine basin of Northern Rhodes at the northernmost tip of the island and occupies the geographic triangle which is formed by the two coastlines on the one hand and by the hills of Monte Smith and Rodini on the other hand.

In its northern extremity the area is plane but moving towards the south-southwest the morphological slopes become steeper, locally reaching values over 20%, while in some locations morphological discontinuities can be observed especially in the area north of the Monte Smith hill. Is characterized by a rapid and rather anarchous growth during the last years, a large population (about 50.000 people) and an enormous touristic development and belongs therefore to the most seismic risky areas of Greece.

Three geological formations outcrop in the city of Rhodes and the adjacent areas: the Upper Pliocene - Lower Pleistocene Asgourou Formation, the Pleistocene Rhodes Formation and the recent Holocene Deposits (**Fig 3**).

Asgourou Formation

The Asgourou Formation covers the greatest part of the city. It consists mainly by lacustrine mars, clays and silts with some remarkable intercalations of conglomerate and sandstone horizons. The Upper Pliocene - Lower Pleistocene age of the Formation has been established by numerous micro- and macrofossils (Mutti et al 1970, Meulenkamp et al 1972, Broekman 1974). The frequent lateral and vertical lithological alterations within the Asgourou Formation reconstruct the rapid changes of its deposition environment between lacustrine, fluvial, deltaic and brackish conditions.

Typical outcrops of the lithostratigraphic sequence of the Asgourou Formation occur along the northwestern flanks of Mt. Smith in Kritika area. Within the 130 m thick marls, clays, silts and fine sands of the formation, outcropping in Kritika area, three at least conglomerate horizons of up to 10 m thickness are visible. They interrupt the uniform relief of the slope creating significant morphological discontinuities. The clastic sediments dip usually with 5^{o}-10^{o} to ESE except in the vicinity of faults where the bedding is disturbed.

From the engineering geological point of view the formation offers a more or less negative foundation basement due to its poor cohesiveness and seems to be very liable to landslides, while, locally, it amplifies the seismic intensity. The greatest part of the new city of Rhodes is based on top of these materials.

Rhodes Formation

The Pleistocene Rhodes Formation overlies conformably or slightly unconformably the clastic sediments of the Asgourou Formation. The transition to the Rhodes Formation marks a final change of the deposition environment from terrestrial - lacustrine - brackish to marine conditions. The upper beds of the Asgourou Formation just below the contact to the Rhodes Formation are characterized by cm-thick horizons of brown to yellow marls and silts alternating with white calcitic horizons.

Rhodes Formation itself consists mainly of marine bioclastic massive limestones of up to 30 m thickness. They crop out within the city of Rhodes and build up usually the top of the hills of the area.

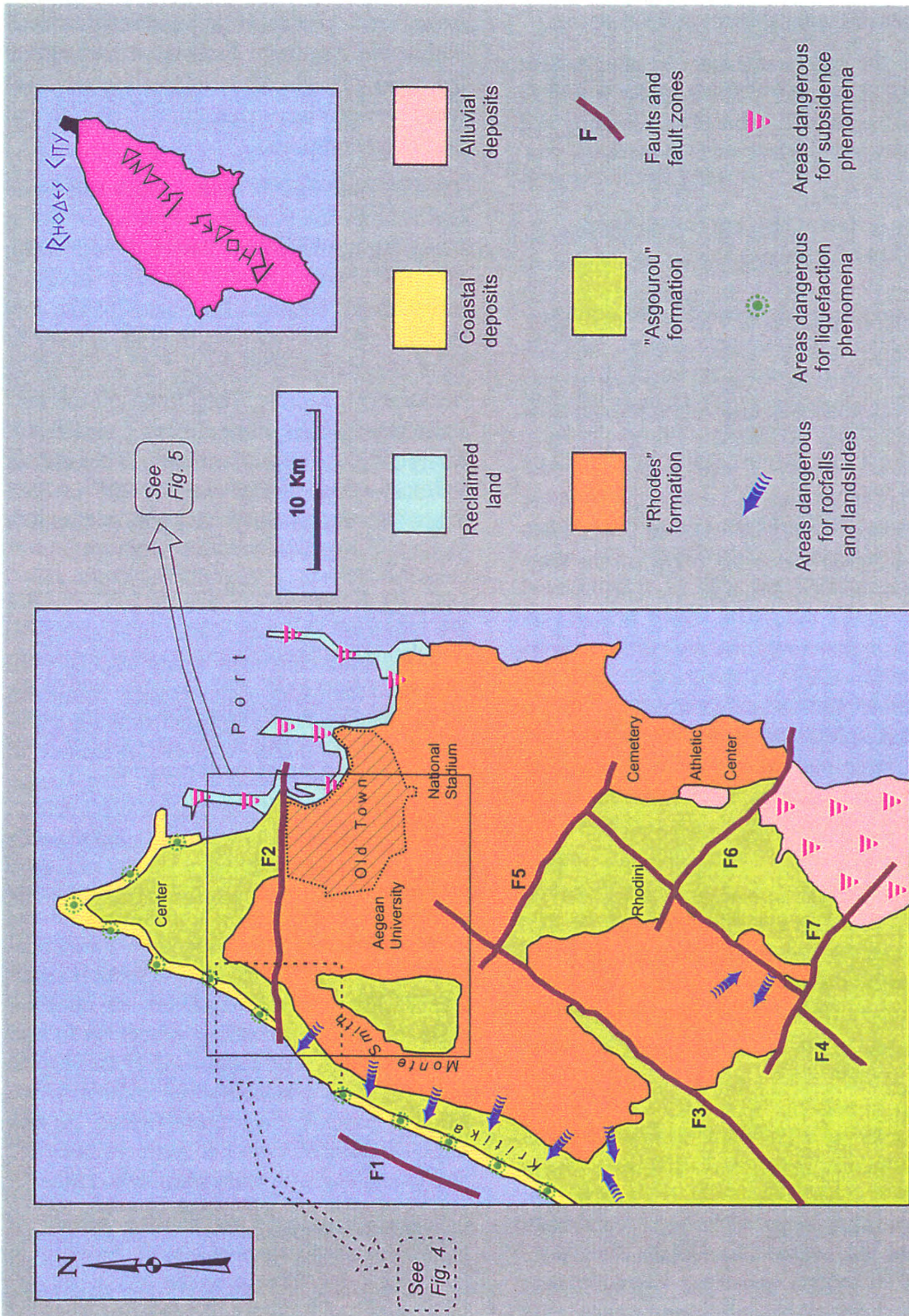

Fig. 3: *Simplified geotechnical map of Rhodes City*

faces of the slight angular unconformities and of the terraces and flattening surfaces which follow the bedding,

- the asymmetric development of the drainage pattern and
- the asymmetric distribution of the morphological slopes in SE-NW direction - the NW-facing slopes are almost always much steeper than the SE-facing ones.

The rotational movement is under the control of the interaction of two fault systems running perpendicular to each other (**Fig. 3**).

The first fault system contains three (F1, F3 and F4) normal faults/fault zones of SW-NE trending, which run parallel to the bedding and to the axis of rotation and dip NW-wards, antithetically to the bedding. This fault system offsets stepwise the bedding of the Asgourou and Rhodes sediments creating steep NW-dipping slopes and slightly inclined, SE-dipping terraces and flattening surfaces following the bedding of the sediments. The vertical displacement between the foot wall and hanging wall of each of F3 and F4 fault zones is 30 - 40 m while the total vertical offset along the F1 fault zone must exceed 200 m.

The F1 fault zone runs offshore, parallel to the northwestern coast of the city. It is responsible for the creation of the steep northwestern slopes of Mt. Smith along which rock falls and land slides are very frequent. Falling rocks of up to 10 m diameter or more are visible along the coastal road connecting the Kanaris Beach of the city of Rhodes with the Kritika area (**Fig. 4**). They derive either from the conglomerate horizons of the Asgourou Formation occurring along the slope within the thick marls and clays and/or from the bioclastic limestones of Rhodes Formation resting on top of the slope.

The F3 fault zone runs across the western part of the city, from Rhodopoula in the SW to the Arapaki area within the city of Rhodes in the NE. It produces a clear offset of the base of Rhodes limestones and creates a remarkable morphological discontinuity running parallel to Petridis street in the southwestern part of the city. The F4 fault zone runs parallel to the Rhodes - Lindos road and to the Rhodini river in the southern part of the city crossing the Rhodini area. The second fault system includes four faults / fault zones (F2, F5, F6 and F7) which trend E-W to SE-NW, perpendicular to the bedding and the traces of the first fault system. They are normal faults/fault zones dipping to N or NE and are characterized by an increasing vertical offset going from ESE to WNW along their trace. This differential movement between the edges of the fault traces supports or is caused by the ESE-ward rotational movement of the area.

The F2 fault zone runs E-W along the foot of the northern slope of Mt. Smith and through the northern branch of the Medieval Trench, separating the northern flat part from the rest of the city (**Fig. 5**). The vertical displacement of the base of Rhodes limestones at the western edge of the fault zone exceeds 60 m. Further to the East, near D'Amboise Gate, it is reduced to 10 - 15 m, while at the eastern edge of the zone, near the port, it is worthless.

The F5 fault zone runs NW-SE through the city of Rhodes, parallel to the Anna-Maria street and is visible from the Arapaki area to the eastern coast of the city. The vertical offset of the Fault zone at its northwestern edge is about 20 m while at the eastern coast is reduced to less than a few meters. It is worth noting that the Rhodini river, running SW-NE parallel to the F4 fault zone at its longest part, turns to SE parallel to the F5 fault zone at their crossing. The F6 and F7 fault zones produce only slight morphological discontinuities and displace the trace of the F4 fault zone.

Geodynamically induced hazards

Seismic hazard

In order to reduce the seismic hazard in the city of Rhodes, the locations where rock for-

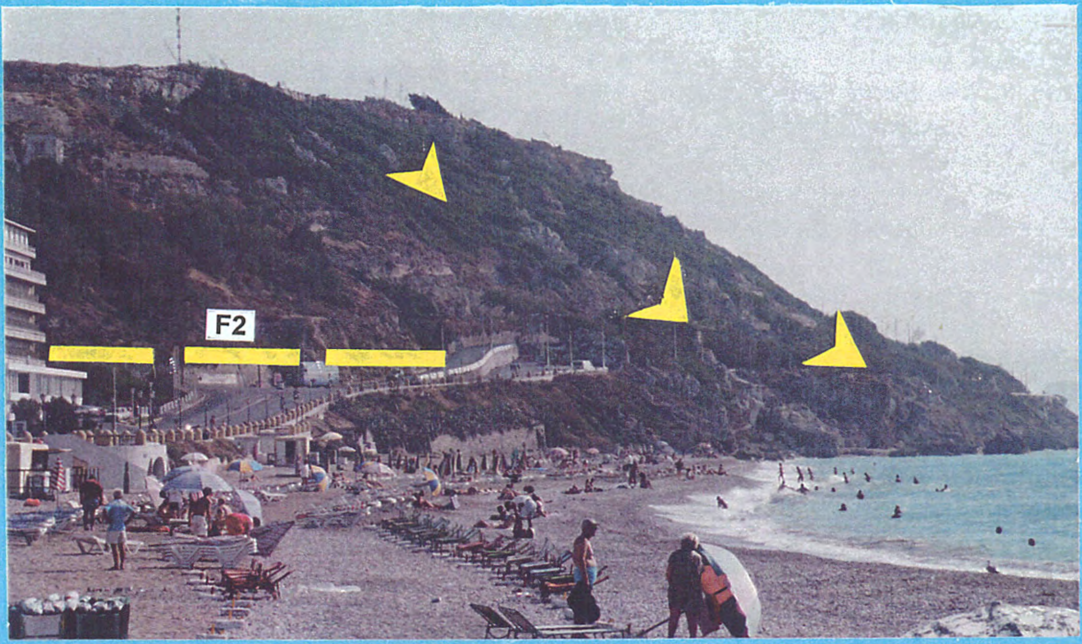

Fig. 4. *View of the steep slope of the Monte Smith at the western edge of the F2 fault zone near Kanaris beach. Falling rocks of up to 10 m diameter are visible along the coastal road.*

Fig. 5. *View of the City of Rhodes with the Old Town and the M. Smith hill. The F2 fault zone is running along the northern slope of M. Smith, through the houses and the Medieval Trench.*

mations outcrop were selected for construction activities (e.g. Rhodes formation) while other areas where formations with a negative response to the seismic events prevail, were avoided. This is deduced by the fact that in all historical times, from Classical times up to Middle Age the important buildings and the fortification walls were founded solely on the Rhodes formation. Typical examples are the Stadium, the Temple in Monte Smith and the Medieval town, which are entirely founded on outcrops of the Rhodes formation.

On the other hand, nowadays this measure was not always followed and thus the present city of Rhodes was quickly expanded on some not so favorable areas resulting in increasing the seismic hazard. The case of the foundation of large structures on loose soil formations which had covered ancient ruins that were founded on the Rhodes formation is quite characteristic.

Active faults

A very important factor is the presence of the numerous active faults and fault zones which cross the area and create significant morphological discontinuities even within the city of Rhodes. It is remarkable that the F2, F3, F4 and F5 fault zones run through the houses, hotels and public buildings of the city and consist a serious possible future threat.

The most important is the F2 fault zone, running along the northern slope of Monte Smith and the northern section of the Medieval Trench. In the area of the foot of Monte Smith no evidence of activity of the fault within historical times were observed owing mainly to the existing landslide phenomena and to the instability of the Asgouros formation members. On the other hand, at the opposite end of the fault close to the old city, the fault is intersecting both the walls and older monuments and has caused deformation of their structural elements either of plastic or of brittle character (**Fig. 6**). Moreover it has noticeably displaced carved monuments on the geological Rhodes formation.

This fact proves the reactivation of the fault surface within historical times, however the time period of this activation cannot be determined with greater accuracy. This reactivation took place either at a slow rate, in the form of creep, or suddenly during a seismic event. Taking into account that the statue of "Colossos" is founded in this area (Konstantopoulos 1986, Mastrapas 1993) it is quite probable that the collapse of the statue and the reactivation of the fault surface during the 227 BC earthquake are interrelated. As it is known, significant phenomena of amplification of the seismic motion occur at either side of the seismic fault which result in the occurrence of high intensities (Lekkas, 1996).

The consideration of the reactivation of the fault is also supported by the fact that during this earthquake a displacement of the coastline took place in the western side of the city (Pirazzoli et al. 1989) which in turn was possibly caused by the displacement of the fault blocks.

Landslide phenomena

The NW-facing fault-created steep slopes of the area are the most hazardous areas for their appearance, which is favored by the geological structure. The cohesive conglomerate horizons intercalated within the soft marls of the Asgourou Formation as well as the massive Rhodes limestones resting on top of the Asgourou marls are the source horizons of the falling rocks, while the marls themselves are prone to sliding phenomerna. They are visible along many slopes of the area but most impressively along the road connecting the city of Rhodes with Kritika area at the northwestern coast.

According to historical studies (Pirazzoli et al. 1989) the road network connecting the city of Rhodes with the western side of the island and other cities there (Ialissos, Kamiros, e.t.c.) was many times under restoration. The repeated restoration works seemed to follow the succes-

Fig. 6. *Fracturing and bending of the structural elements of the Medieval Wall induced by differential subsidence movements in the vicinity of the F2 fault zone.*

sive destruction from the landslides which were enfavoured both by the steep slopes and by the nature of the Asgouros formation which is prone to these phenomena.

Coastline vertical movements

Several paleo-shorelines are visible mainly along the eastern coast of the island lying up to about 4 m above the present mean sea level. and Pirazzoli et al (1989) studied them and proved repeated vertical movements of the coastal region during the last 6.000 years caused by fault activity. The most impressive event was the sudden uplift of about 3,8 m of the northernmost part of the island, including the area of the city of Rhodes, which is likely to be linked with the earthquake which destroyed the Colossus in 227 B.C.

In the littoral area of Korakoneri on the eastern coast of the city, quarried areas were observed, intended for the production of flagstones from the Rhodes formation (**Fig. 7**). These quarries are found today below the sea level reaching even a depth of 1m., indicating a subsidence movement of 1-2 m. approximately from the Roman period up to present times (Pirazzoli et al. 1989).

This movement of the land either occurred suddenly due to an earthquake or progressed gradually in order to attain an equilibrium. Due to these phenomena and to the concurrent change of the coastline, this field stoped being used, while inhabited areas at either side were also probably abandoned. According to historical evidence (Pirazzoli et al. 1989) the area under discussion was submerged during the first Byzantine period. If this subsidence was due to a seismic event it could be inferred that it probably corresponds to the earthquakes of 477 and 516 AC.

Tsunamis

The entire coastal zone of the city of Rhodes can be considered as being exposed to gravitational see waves (tsunamis). The biggest tsunami that has been recorded in Rhodes island, had a maximum height of 3 meters and was caused by an earthquake of magnitude M=7.2 in the offshore area east of the island of Rhodes on the 3rd of May 1481 AC. Tsunamis have also been recorded in other islands of SE Aegean, such as in Kos (554 AC), in Chalki (1843), in Karpathos (1948) and in Rhodes (142 AC).

STOP 2

THE CITY OF LINDOS

History of the City

According to the mythology it was Lindos, the grand son of the sun-god Helios, who first colonized this place. Archaeological finds show that the area had been inhabited in the Neolithic age, while Mycenaean graves indicate the presence of Achaeans here too.

Lindos was one of the three city-states founded by the Dorians on the island in the 11^{th}-12^{th} century BC. Lindos developed a maritime character and became in the 8^{th} to 6^{th} century BC an important commercial center.

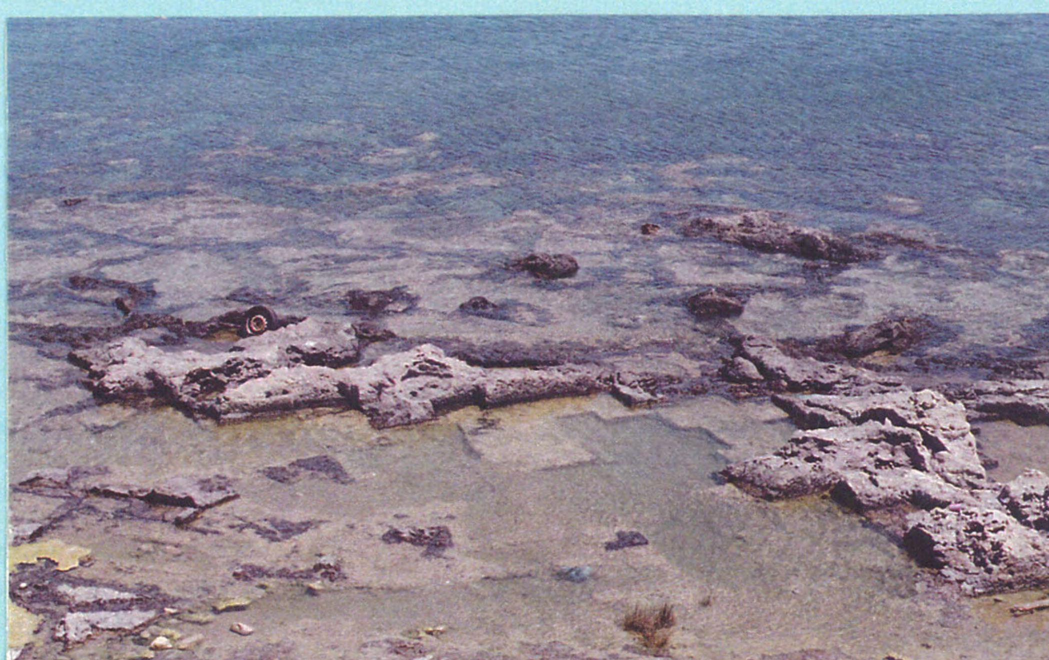

Fig. 7. *Quarried area of Roman time at the eastern coast of the City of Rhodes, lying today at depth up to 1 m below sea level, due to recent neotectonic subsidence movement.*

The most impressive of the antiquities of the city is the Acropolis with the Temple of Lindian Athena which was founded in 330 BC. Within its classical antiquities are included also the Necropolis and the Amphitheater, which was curved out of the rock.

The mediaeval remains include a Byzantine Church of Our Lady and a number of imposing houses dating from the time of the Knights of St. John.

Therefore, Lindos belongs to the traditional towns and villages, with very important historical, cultural and touristic significance, which are under the protection of the Hellenic government. Due to the individual geotectonic position of Rhodes island, Lindos is threatened by various geological hazards, such as the seismic activity, the reactivation of faults, rock falls and land slide phenomena, rapid changes of the present slope morphology, coastline displacement, etc., which are associated with the high seismicity of the area

Geological frame

The greatest part of the area adjacent to the town of Lindos **(Fig. 8)** is covered by calcareous and clastic metamorphic rocks of the homonymous "Lindos" unit, the lower alpine geotectonic unit of Rhodes, equivalent to the "Mani" unit of the Hellenides (Mutti et al 1970, Meulenkamp et al 1972, Lekkas et al 1993). The calcareous formations are represented by Cretaceous to Upper Eocene, thick- to medium-bedded marbles. The clastic sediments are represented by the flysch formation (Upper Eocene - Lower Oligocene?) consisting of alternations of sandstone, tourbiditic sandstone and schist of low grade metamorphism. The engineering behaviors of both aforementioned formations are rather good.

The post-alpine sediments of the area ("Asgourou" formation, "Rhodes" formation and recent alluvial and coastal deposits) overly unconformably the metamorphic basement and consist of river fluvial, brackish and marine water deposits of Pliocene-Pleistocene age.

The "Asgourou" formation (Upper Pliocene - Lower Pleistocene, Mutti et al 1970), is the lowermost post-alpine formation and consists of marly lacustrine deposits and alternations of conglomerate and sandstone. The geotechnical parameters vary a lot depending on the lithology while at certain locations a very loose weathering mantle occurs.

The "Rhodes" formation consists of bioclastic limestone of Pleistocene age, while in certain locations transitional layers may occur at the base of this formation, consisting of alternations of brownish sandstone, yellow marl and calcareous horizons reaching just a few meters in total thickness. The geotechnical behavior of this formation are relatively good, however very significant problems can occur which are described below.

It is worth noting that the main planation surfaces of the area, which are the plateau of the Ancient Tomb and the plateau of Lindos village itself, have been developed on the bedding of the Rhodes and Asgourou formation respectively.

The recent Holocene deposits are represented by alluvial formations (loose material of various size), coastal deposits (sand and gravel), torrential deposits (mainly coarse-grained and angular material, pebbles and less often gravels), talus screes (loose angular material of various size) and man-made deposits that can be found at certain locations within the region of Lindos as well as at some sites of archaeological interest. These are restricted both in thickness and lateral extent and their composition varies. In most of the cases their geotechnical behavior are quite poor.

Neotectonic activity and related hazards

The major area of Lindos peninsula (**Fig. 8** & **9**) is characterized by the existence of several active and seismic faults and fault zones

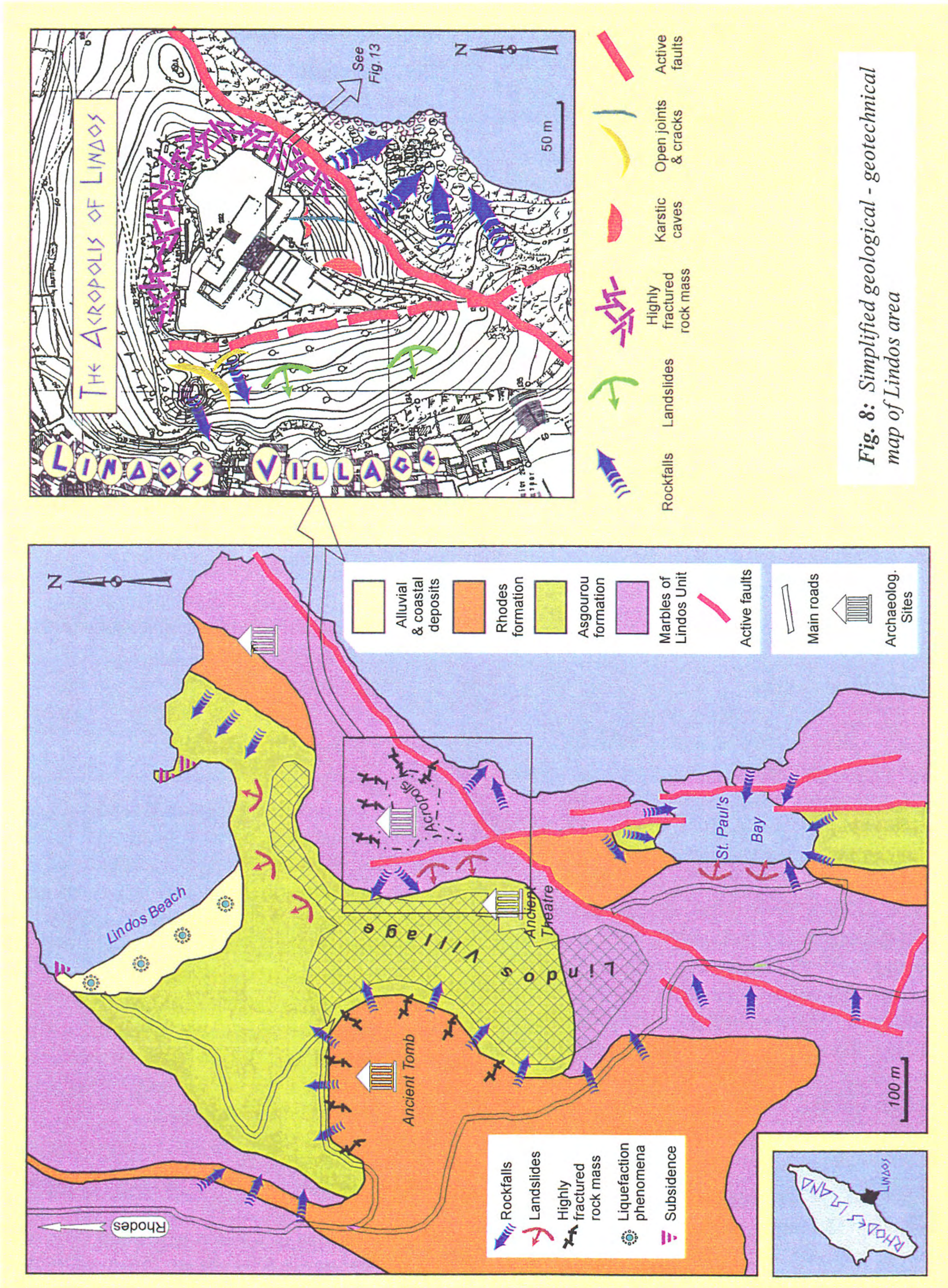

Fig. 8: *Simplified geological - geotechnical map of Lindos area*

(Gauthier 1979, Lekkas et al 1993). The most important neotectonic macrostructure over the area of Lindos is a first order listric neotectonic fault, trending SSE-NNW. This kilometric scale F1 fault zone (**Fig. 10**) separates the subsiding "Lindos fault-block" to the east from the uplifting "Pylon fault-block" to the west and it has been reactivated during the present century.

Second order faults run also through the area of Lindos and increase the seismic risk of the ancient village and the antiquities. The F10 and F11 fault zones represent essentially the boundaries of the village of Lindos to the SE and E respectively (**Fig. 11**). The F1 and F17 fault zones constitute a major problem for the touristic activities at the beach of the Vlycha bay. The F1 fault zone crosses both exits of Lindos towards Rhodes and Lardos, and as a consequence, any potential displacement along this fault zone could cut off the village of Lindos from the rest of the island. The exit to Rhodes is also threatened by the F17 fault, while the exit to Lardos area by F7 as well.

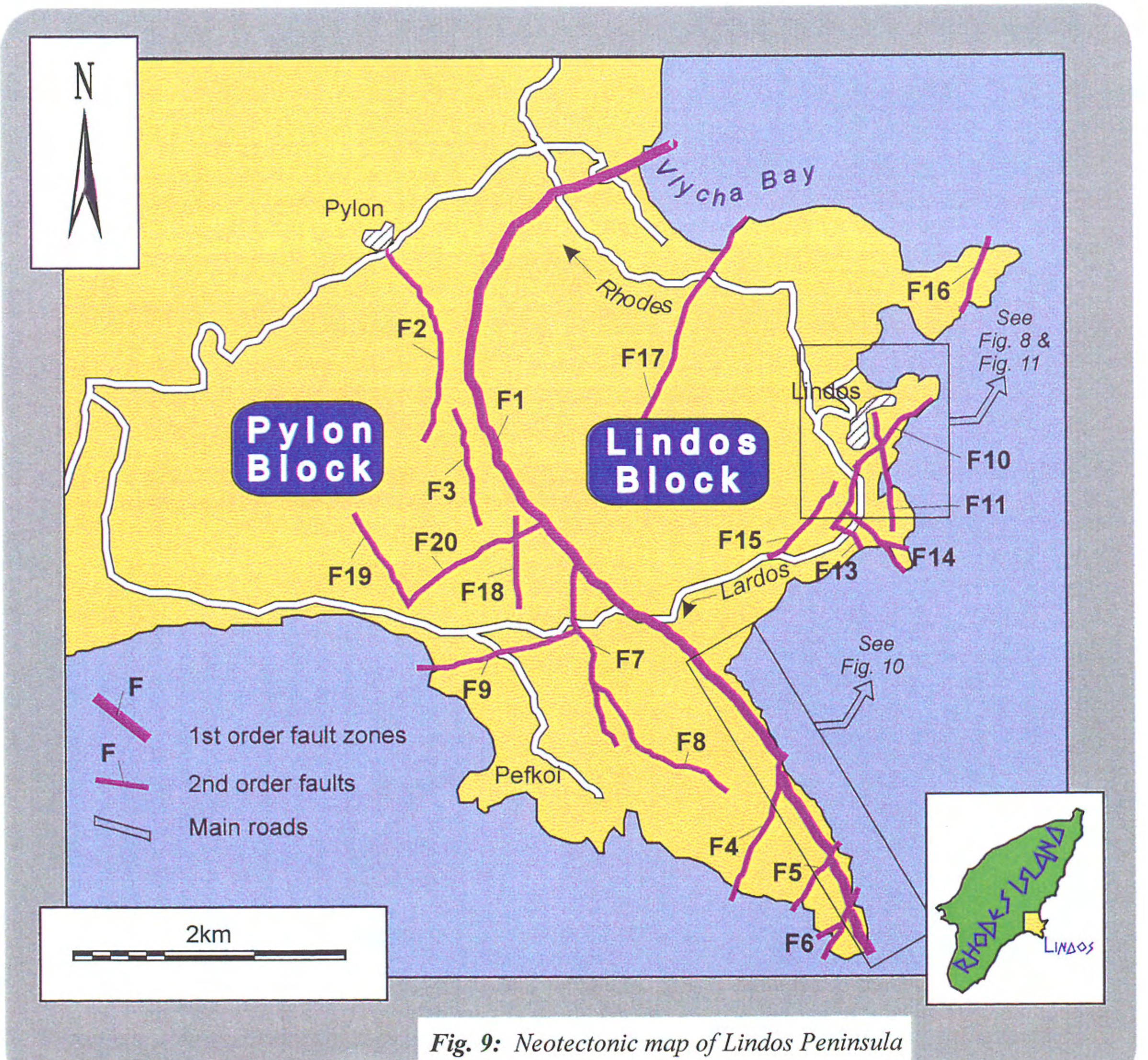

Fig. 9: Neotectonic map of Lindos Peninsula

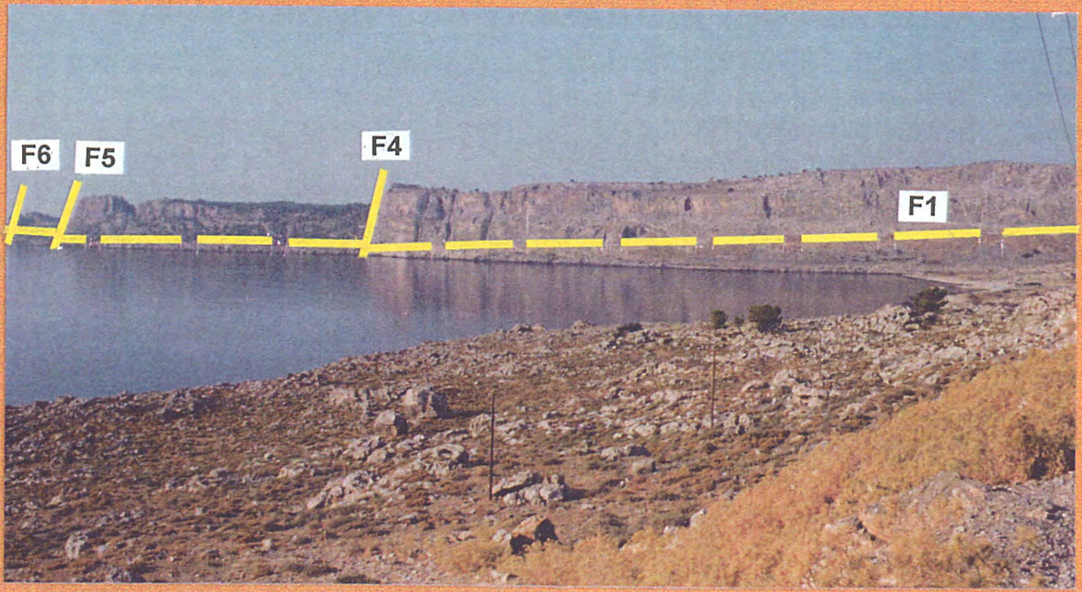

Fig. 10. *View of the F1 fault zone at the area of Avlonas (to the south of the village of Lindos), which trends to the NNW-SSE direction, parallel to the coast line. The F4, F5 and F6 faults, which cut the previous fault zone trending to the NNE-SSW direction, are also visible.*

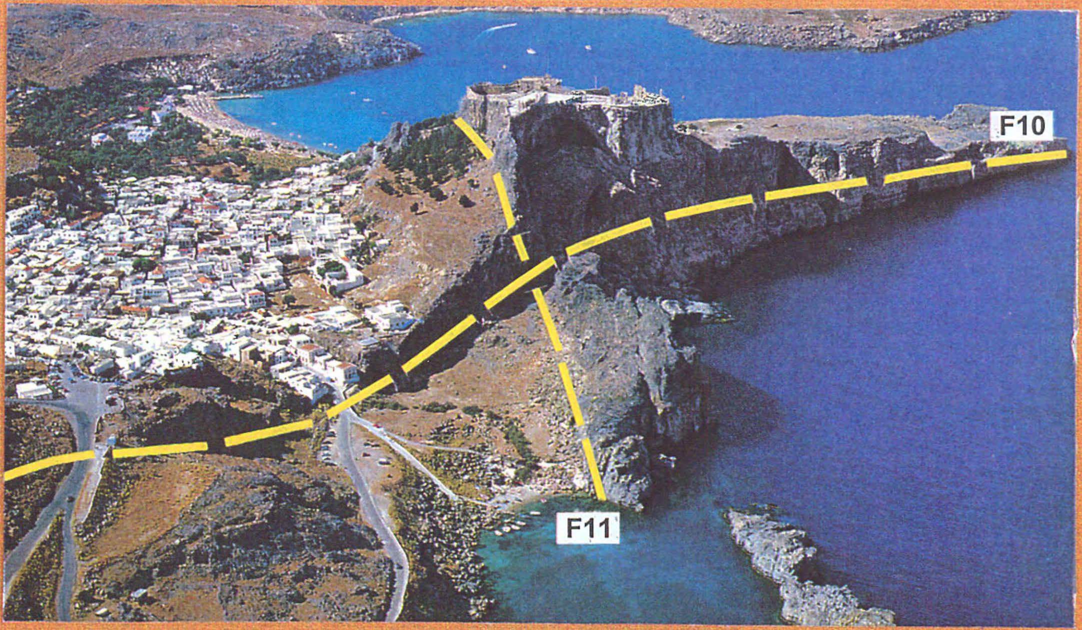

Fig. 11. *Aerial view of the village and the Acropolis of Lindos. The F10 and F11 fault zones, trending respectively to the NNE-SSW and N-S direction, are visible.*

The intense morphological relief of the area of Lindos is largely due to the very intense neotectonic processes. The most important morphological features in the major area of Lindos, such as the steep slopes of the Acropolis of Lindos, the plateau of Ancient Tomb, the St. Paul's Bay, the steep slopes of the eastern coast and many others, are associated with the presence of active faults. These faults can create minor or major morphological discontinuities, depending on the magnitude of vertical displacement. The fault zones activity influences significantly the landforming process of planation surfaces and terraces, since they intersect and vertically displace them, thus complicating their correlation.

The area of Lindos exhibits a quite length of coastline, which is moreover intersected by a great number of active faults and fault zones. If we take in mind the results of the recent surveys (Pirazzoli et al 1989), which confirmed at least six distinct displacements of the coastline of Eastern Rhodes, during both historical and more recent times, the inherent risk for the area becomes obvious (**Fig. 12**).

The areas which are susceptible to rock falls in the Community of Lindos include the steep slopes, the uppermost part of which is covered by bioclastic limestone of the "Rhodes" formation, as well as the steep slopes of crystalline limestone of the "Lindos" unit.

Landslide phenomena could occur along the slopes which are made of the "Asgourou" formation. Such slopes can be observed in the area around the village of Lindos and above the beach of Vlychas bay.

On the contrary, a single tension crack, run-

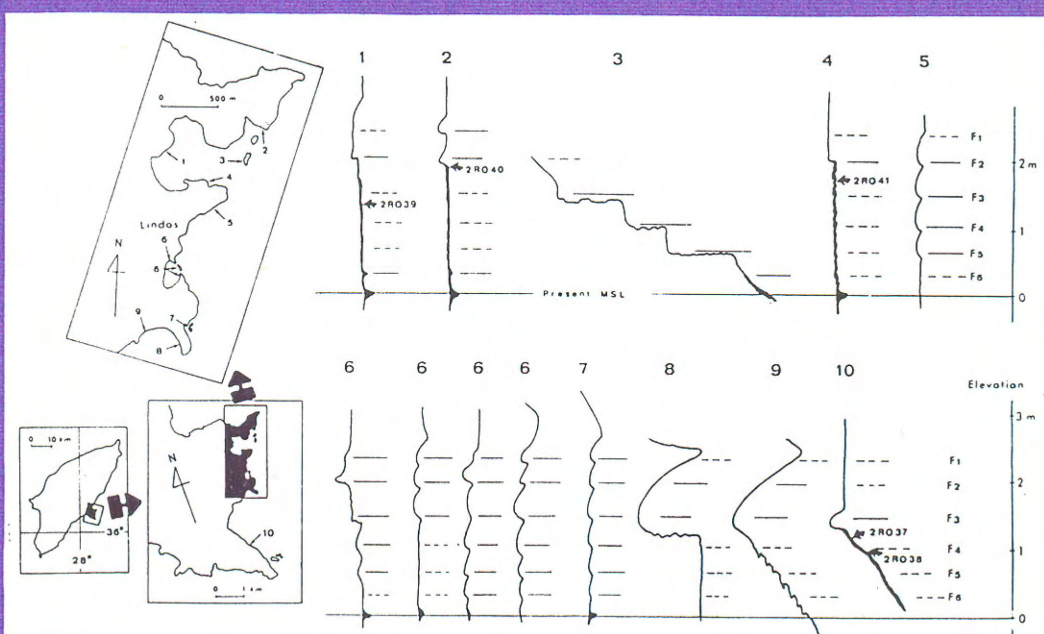

Fig. 12. Marks of emerged Holocene shorelines in the Lindos area from Pirazzoli et al (1989).

Fig. 13: The tension crack located at the eastern side of the Acropolis hill and the karstic cave located right at the core of the hill, underneath the Temple of Athena Lindia.

ning all the way down parallel to the eastern part of the cliffs, as well as two more open discontinuities located at the southwestern and northwestern cliff faces, may induce possible slope stability problems, as rock falls and block sliding (**Fig. 13**).

The occurrence of subsidence phenomena becomes likely only in the coastal plane areas, which are covered by loose alluvium deposits. A potential occurrence of liquefaction is not expected to have a significant impact in the Community area. Liquefaction could only be caused in the sandy beaches of the Community, on which no structures exist, exempt for the Case of Vlycha bay where a number of hotels and houses exist.

Geotechnical conditions of the Acropolis of Lindos

The acropolis of Lindos is a naturally fortified hill, which corresponds to a typical tectonic horst. The steep cliffs of the western and eastern side of the hill match more or less with the two active normal faults (F10 and F11), which form the horst (**Fig. 11**). The prevailing rock formation of the acropolis consists of crystalline, intensively karstified, medium to thick bedded limestones (marbles) of Cretaceous age of Lindos unit.

A detailed and systematic study of the acropolis hill rockmass, carried out by Kazilis & Dalias (1988) revealed the presence of three sets of discontinuity surfaces (two joint-sets and the bedding) as well as various others fractures, which can not be easily classified but play an important role in the development of kinematically assessed instability conditions. The orientation of the two joint-sets and the bedding do not favors instability conditions. Additionally, potential serious instability problems, able to destroy completely the antiquities of the Acropolis, may occur, induced by the presence of a big karstic cave located right at the core of the hill, underneath the Temple of Athena Lindia (**Fig. 13**).

STOP 3 — CHAMBICA BEACH

The Tsambika beach is one of the finest beaches on Rhodes with particular beauty. It is also very interesting in terms of neotectonic vertical movements, due to the spectacular outcrop of preserved marks of Holocene shorelines.

The greater area of the beach of Tsambika is characterized by the presence of numerous active faults, which create significant morphological discontinuities and steep slopes, and complicate the geological structure of the region.

The most important of them is trending to the E-W direction and represents the southern border of Tsambika Bay. From kinematic point of view this active fault is characterized by creep movement and causes a lot of damages to the Rhodes-Lindos national road (**Fig. 14**).

Thick bedded limestones of the Archagelos/Tripolis unit build up the steep hill to the north of the beach, on top of which is located the Byzantine monastery of Tsambika, dedicated to the Blessed Virgin. Pliocene clastic sediments of the Asgourou formation and Pleistocene bioclastic limestones of the Rhodes formation occur around the hill creating morphological terraces, which are displaced vertically due to the activity of the active faults.

Detailed studies along the cliffs on both sides of Tsambika beach, carried out by Pirazzoli et al (1989), revealed the existence of six distinct shorelines (**Fig. 15**). The oldest one lies at +2,3 m. to +2,45 m. above present sea level and is older than 5000 yr B.P. After that the sea level had first dropped below +1,15 m. and a short time later had risen to the uppermost shoreline, slightly above +3 m. and remained stable until at least 3600 yr B.P. About 2600 yr B.P. the sea level was at +1,8 m. to +1,9 m. above present sea level, while the youngest paleoshoreline lies at +0,5 m. and is dated 1205±100 yr B.P.

Fig. 14. *The active fault of the southern margin of Tsambika beach. From the kinematic point of view this fault is characterized by creep movement and causes a lot of damages to the Rhodes - Lindos national road.*

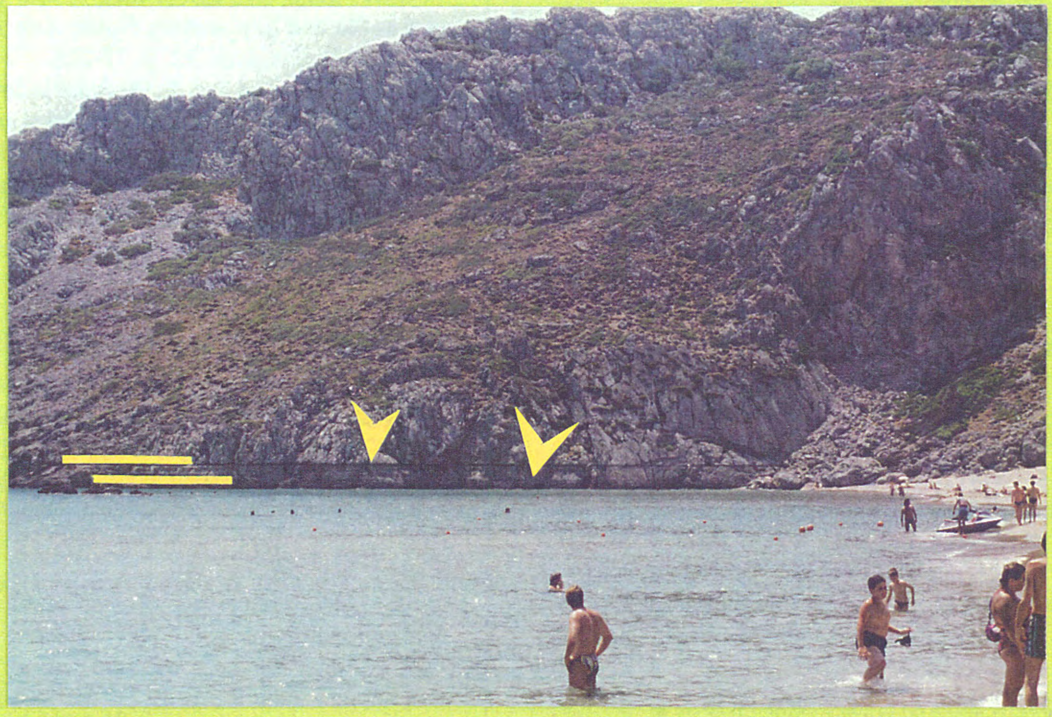

Fig. 15. Emerged Holocene shorelines in the area of the beach of Tsambika.

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