*Risk Analysis, Brebbia, Rubio, Uso (eds),WitPress 1998, vol. 2, p. 169-178*

# A proposal for earthquake emergency planning of Rhodes Municipality (Greece)

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## Abstract

The town of Rhodes (Rhodes island, southeastern Greece) exhibits increased seismic risk which is attributed to its position in the vicinity of the Aegean Arc and also the geo-dynamic phenomena. Additionally, the risk is particularly high due to the contemporary regional structure and social characteristics. In order to reduce the consequences from a future earthquake an integrated study on earthquake emergency planning and protection was carried out for the Rhodes town, and parts of this research are presented in this work. In particular, based on the geo-dynamic framework but also the urban structure characteristics of the town a management plan for emergency situations which appeals the local government and the local people, is proposed. The elaboration of this project was based among other on the use of smart information systems (G.I.S). It includes suggestions for assemblage points, camp sites, suggestion for spaces to re-accommodate public services, distinction between different action fields, etc.

## 1 Introduction

The city of Rhodes lies at the very north edge of Rhodes island, the biggest and most touristically developed island of Southeastern Aegean. Its high seismicity is attributed to its position in the eastern part of the active Hellenic Arc, where a sinistral almost horizontal movement between the subducting African Plate and the overriding European Plate is in progress. Furthermore, the island is characterized by the occurrence of subsequent earthquake induced geodynamic phenomena (Lekkas,[1]), such as the action of active faults, changes of the shore lines, landslides, which increase the present risk.

The city of Rhodes itself is characterized by a rapid and rather uncontrolled growth in the last years, a large population (about 60.000 people) and an enormous touristic development, it therefore belongs to the most seismic risky areas of Greece.

Within this framework with the particular local conditions and characteristics of the Rhodes town is considered worthwhile to accomplish an earthquake planning and organization project, so as to minimize the consequences from a potential earthquake (Lekkas,[2]). In the present study only the geological–geodynamic and regional structure data are shown, on which the earthquake emergency action plan was constructed and designed to apply to the local government and the population.

# 2 Geological Frame of Rhodes Municipality

The area occupied by the Municipality of Rhodes is located in the northeastern part of the post-alpine basin of Northern Rhodes. The following formations occur in the area (Fig. 1) (Mutti,[3] Lekkas,[1]):

**Asgourou Formation**. It consists mainly by lacustrine marls, clays and silts. The age is Upper Pliocene - Lower Pleistocene. The various fine grained sediments of the Asgourou Formation, as marls, clays, silts and sands consist a more or less geomechanical negative foundation basement due to their poor cohesiveness.

**Rhodes Formation**. Overlies conformably or slightly unconformably the clastic sediments of the Asgourou Formation. Rhodes Formation itself consists mainly of marine bioclastic massive limestones of up to 15m thickness. They offer a very good formation basement due to their massive character.

**Holocene Deposits.** The youngest formations of Rhodes Municipality are the Holocene and recent alluvial, coastal and river deposits and the debris flows and rock falls outcropping along the steep slopes of the area.

The formations, which occur in the area of Rhodes municipality are cut by the following faults and fault zones. Especially:

The first fault system contains three (F1, F3 and F4) normal faults of SW-NE trending, which run parallel to the bedding and to the axis of rotation and dip to the northwest, antithetically to the bedding.

The **F1** fault runs offshore, parallel to the northwestern coast of the Municipality. It is responsible for the creation of the steep northwestern slopes of Mt. Smith along which rock falls and landslides are very frequent. The **F3** fault runs across the western part of the Municipality 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 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 (F2, F5, F6 and F7) which trend E-W to SE-NW, perpendicular to the bedding and the traces of the first fault system.

The **F2** fault runs E-W along the foot of the northern slope of Mt. Smith and through the northern branch of the Medieval Trench, dividing the northern flat part from the rest of the city (Fig. 2). The **F5** fault 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 **F6** and **F7** fault produce only slight morphological discontinuities and displace the trace of the F4 fault zone.

All the above described faults cut off the Pliocene and Pleistocene sediments of the area and produce more or less remarkable geomorphological structures. Therefore they can undoubtedly be considered as active faults.

# 3 Geodynamic phenomena

In the area of Rhodes town is plausible to occur, during a seismic event, geodynamic phenomena induced by the earthquake, which may increase significantly the overall consequences (Fig. 1, 3).

A very important factor is the presence of the numerous active faults and fault zones, which cross the area of the Municipality 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 consists a serious potential threat. For example the General Hospital of the Island lies about 100 m away from the trace of the F2 fault zone. This fault zone divides also the triangular northern part of the city from the rest of it. A possible reactivation of it could cause serious damages and destroy the roads connecting the two parts of the city.

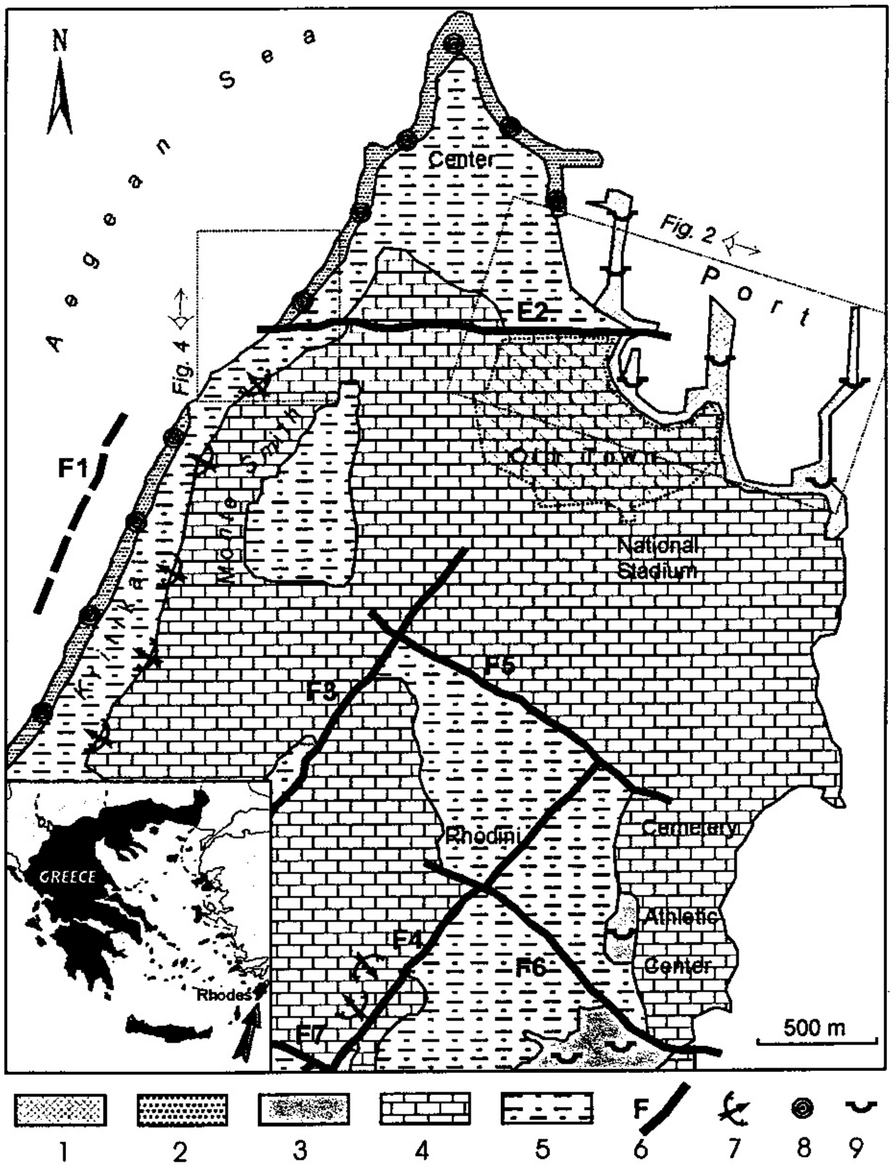


Figure 1: Geological map of the studied area (1. Reclaimed land, 2. Coastal deposits, 3. Alluvial deposits, 4. Rhodes formation, 5. Asgourou formation, 6. Faults, 7. Areas dangerous for rock falls and landslides, 8. Areas dangerous for liquefaction phenomena, 9. Areas dangerous for settlement phenomena).

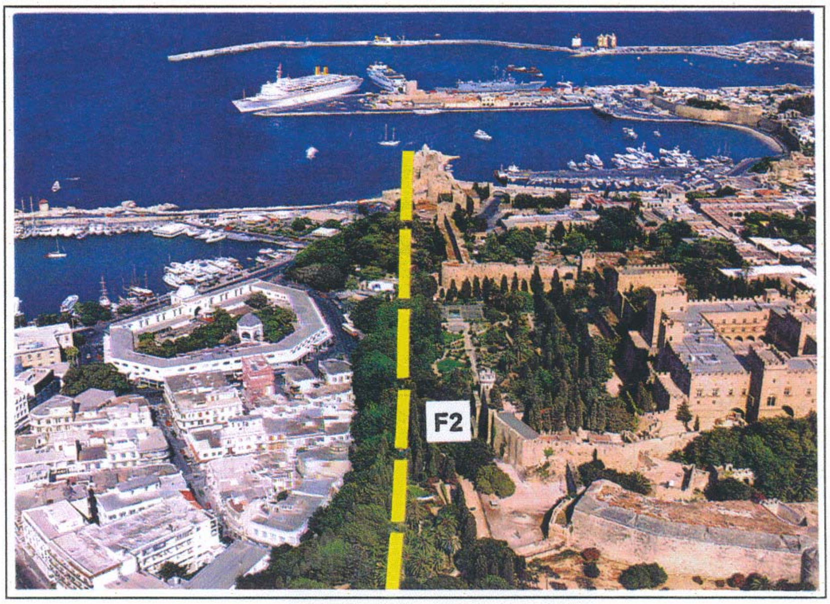


Figure 2: View of the F2 Fault which separates two areas, the old town on the right, which is built on the Rhodes formation and the one on the left, which is based on the Asgourou formation.

Rock falls and landslides are also common destructive phenomena, which appear along the steep slopes of the area either independently, or following a seismic activity. The NW-facing, fault-created steep slopes of the area are the most hazardous areas, which are favoured 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. They are visible along many slopes of the area but most impressively along the road connecting the city with the Kritika area at the northwestern coast. Additionally the soft marls and clays of the Asgourou Formation favour the occurrence of landslides. Additional settlements are plausible to occur in the harbour buildings as well as in the southeastern part of the Municipality.

Liquefaction and ground sinking phenomena may also appear in areas covered by allouvial and coastal deposits as effects of a seismic activity.

An additional phenomenon is the differential vertical displacement of the shorelines. 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.

It is apparent that the determination of the areas in which potential disastrous earthquake induced phenomena may occur is now essential in order to construct a plan for the reduce of the potential hazards to the population.

# 4 The regional structure

The case of Rhodes Municipality shows generally some particularities, which affect largely the processes of earthquake planning and organisation and also the accomplishment of an emergency earthquake plan as well as the degree of success of such plan. These particularities concern the modern town-planning, the social and economic conditions of the Municipality.

The regional structure and urban pattern framework shows significant centralisation as far as the general functions and the land uses are concerned. Especially the administrative services are gathered in the northern edge of the town where the shopping center and the historical part of the town are situated. The touristic section is more developed in the western part of the Municipality. Reversally, extensive residential areas are located in the eastern and southern part of the town.

During the summer period the number of residents becomes double due to the large number of  tourists and there is large accumulation of the population in the northern triangle where the shopping center, the old town and the western coast which has large number of hotels.

The road network presents a respective centralisation. The main features are the heavy traffic which is mainly shown during summer while the width of the main roads especially in the areas of the shopping center is limited. The road axes, where frequently is observed traffic saturation, are regarded inadequate for the evacuation of the town, however the western axe that links the town with the airport is in risk of rock falls in the area of Monte Smith (Fig. 1, 3, 4).

Special mention must be made about the old part of the town, where the density of the population during the summer period is extremely high and the risk is at a high level due to the increased vulnerability of the buildings and the presence of active faults (Fig. 2).

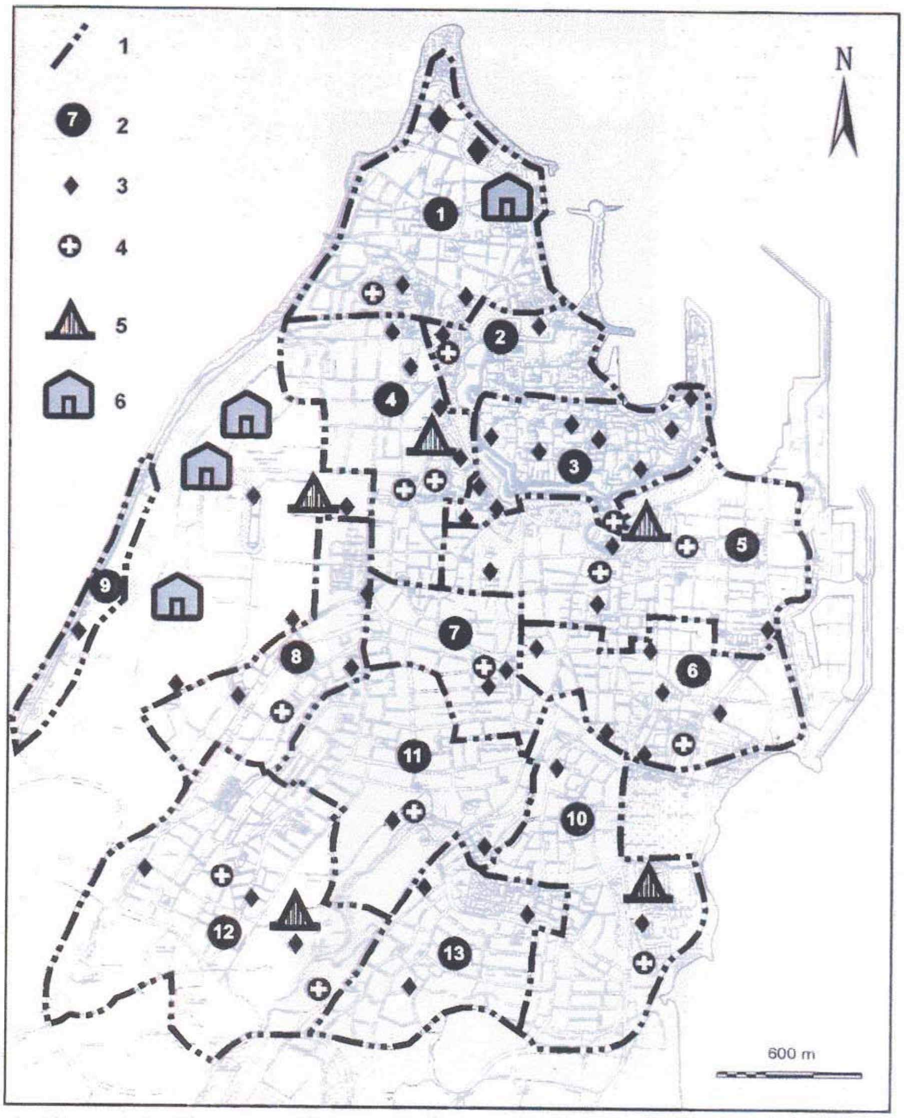


Figure 3: Map with some of the basic elements of the Earthquake Emergency Planning of the Rhodes town (1. Distinction of Sections, 2. Number of Sections, 3. Assemblage points, 4. Health provision and services, 5. Camp Sites, 6. Municipal Coordination Committee).

The structured network of the town consists of buildings, which have been built in different periods, but mainly after 1960 when it was noticed

Figure 4: Boulders that can block the road, which links the town with the airport, in the case of earthquake.

large development in the town as a result of the increase in the flow of tourism. Especially, in the old town all the buildings are aged, while the first buildings were constructed in Medieval times. In the remainder of the town there is a small number of buildings which were built between the beginning of the century and up to 1940, while as mentioned before the vast majority of the buildings were after 1960.

# 5 The basic features of the earthquake planning

The formation of an earthquake emergency plan (Fig. 3) was carried out taking into account a number of facts, but mainly the basic features mentioned in the previous sections. The data processing as well as the decision making was done based on the use of a smart program for management of geographical information (G.I.S) in a computer. In this plan among other it has been made provision for the following:

**Distinction of sections**. The selection has been based in the division of the town in a number of 13 sections where each one corresponds to one or more assemblage sites. In particular sections it has been allowed for spaces of setting up emergency and first aid services. Each divided section presents particular town-planning and population characteristics.

**Assemblage points**. Such spaces are estates, town squares, school yards, football courts, gyms, parks, archaeological sites, playgrounds, gardens, cottages, wide roads, etc., which cover many facilities, crucial or not. Most of these sites are public, however some private ones are also used, those which do not show high risk as far as the earthquake induced phenomena are concerned. It was tried to select these areas so as to have the minimum risk in terms of the occurrence of earthquake induced phenomena or the collapse of adjacent buildings.

**Camp sites**. Three sites in the area of Monte Smith are proposed, which have easy access and are situated in a proper and secure place. Moreover one area in Rhodini which has very easy access from west and another two sites in the football court of Diagoras team, which has relatively easy access too, are proposed. Finally an area which is located within the athletic center, south of the cemetery is also proposed, which shows very good access and in which there is basic infrastructure such as the water supply and drainage system etc.

**Municipal Coordination Commitee**. In occasion of small scale catastrophes, the areas for installing the monitoring instruments are the those in section 1, which are next to the Town Hall. In case of large scale disaster the recommended areas for reaccommodation of the committees are located in the area of Monte Smith and the southern part of the town.

**Transportation**. Special mention must be made to the town harbour which is under the risk of ground settlement. Taking for granted that up to now there is no alternative, all the plausible solutions must be examined, because it is the determinant factor in the earthquake emergency planning as far as the supply of external aid is concerned. Moreover the coastal avenue, which links the town with the airport is in danger of being out of use in case of the occurrence of rock falls, in the area of Monte Smith (Fig. 4).

**Health provision and services**. An important problem is the location of the hospital, which is built on an active fault zone and also the construction is old. Additionally there is difficulty in the access due to the particular characteristics of the road network which links with it. In cases of large scale disasters reaccommodation of the hospital to the southern part of the town and in prefabricated buildings or in the buildings the new hospital in the southern edge of the town is proposed.

# 6 Discussion-Conclusions

It is known that the attempts to minimise the consequences of earthquakes include numerous research projects and actions of multi-tasking character which are distributed in three levels, the prevention, the intervention and the remediation. It is undisputed fact that the more accomplished the approaches and measures taken during the pre-earthquake period in terms of prevention, the more controllable and restricted the consequences will be. The approaches and actions must concern not only the pre-seismic level itself but also the intervention and remediation levels, too.

The basic features of the plan, which have already been presented, concern the emergency period immediately after the disastrous event and applies to the local government and the inhabitants too. However awareness and training must be sufficiently provided during the pre-earthquake period.

Respective plans have been proposed and concern entirely the public services of the town, such as the police, the military department, the firebrigate, the health service, etc., for taking respective actions in periods of emergency. Moreover the external aid is considered significant, but in terms of post-earthquake management only.

Finally one of the interesting features of the proposed plan and the whole program is its flexibility due to the processing of the data by a decision-making system in a G.I.S frame. The potential ability to input new data and form new plans is a significant parameter of the effectiveness of the measures in any time and period.

# References


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