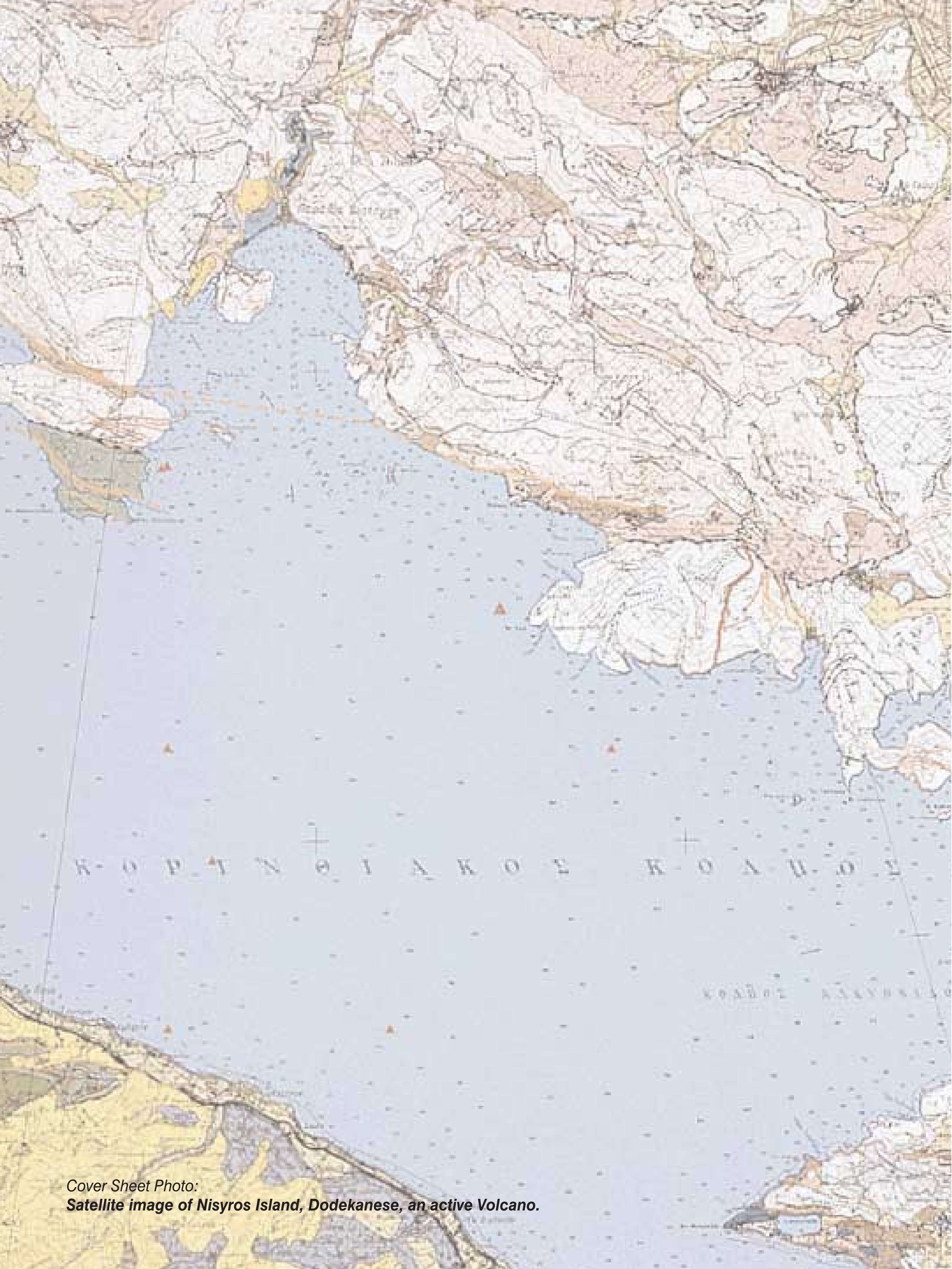
# NEWSLETTER
## of the
# EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES

ISSUE No2
SEPTEMBER 1998
ATHENS

- SEMINARS - SYMPOSIA
- RESEARCH PROJECTS
- NEOTECTONIC MAPS
- TECHNICAL HANDBOOKS

Council of Europe
Conseil de l' Europe




*Cover Sheet Photo:*
***Satellite image of Nisyros Island, Dodekanese, an active Volcano.***

# NEWSLETTER

ISSUE No2 • SEPTEMBER 1998 • ATHENS

*of the*

# EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES

(E.C.P.F.E.)

Council of Europe Conseil de l'Europe

# C O N T E N T S

# P R E F A C E

*The European Centre on Prevention and Forecasting of Earthquakes (ECPFE) is one of the Centres established and operating within the frame of the Open Partial Agreement on "Prevention of Protection against and Organisation of Relief in Major Natural and Technological Disasters". Its activities during the period 1987-1997 have been described in the 1st issue of the Newsletter (July 1997). This 2nd issue of the Newsletter includes a brief summary of the previous activity and a description of the new activities during 1997-1998.*

*The main research project of the Centre in this last period concerns the study of the seismic and related geodynamic activity along the Aegean Volcanic Arc, with focus mainly on the eastern part, around the islands of Nisyros and Kos.*

*The progress report published in this issue includes a wealth of new, mostly unpublished data, obtained by several research groups, working with different methods both onshore and offshore. Taking into account the very limited budget available, these results can be considered as rather impressive.*

*The eventual establishement of ECPFE in the city of Kalamata, SW Peloponnese, and its further financial support from sources other than the Open Partial Agreement of the Council of Europe and the Earthquake Planning and Protection Organisation (E.P.P.O.) of Greece, are expected to produce a new impressive impulse on its activities in the next couple of years.*

**The President of ECPFE and EPPO**

Professor D. J. Papanikolaou

# OPEN PARTIAL AGREEMENT OF THE COUNCIL OF EUROPE - ( OPA )

The Committee of Ministers of the Council of Europe adopted an intergovernmental Open Partial Agreement (EUR-OPA Major Risks-Hazards Agreement), the aim of which was to strengthen European co-operation from a multidisciplinary point of view, on Prevention of, Protection against, and Organisation of Relief in Major Natural and Technological Disasters ( Council of Europe, Resolution (87), 2) , 20 March 1987.

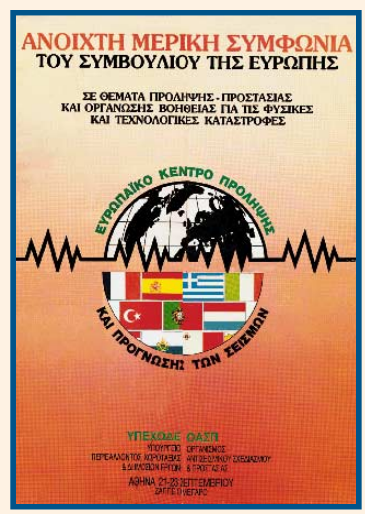
The EUR-OPA, Major Risks was created by France, Spain, Italy, Luxembourg, Greece, Malta, Monaco, Portugal, Democracy of San Marino and Turkey in Athens, in September 1987, in order to respond to the consequences of Major Disasters (earthquakes, volcanic eruptions, etc). The Agreement is open to both member and non-member States of the Council of Europe and currently comprises 21 States .

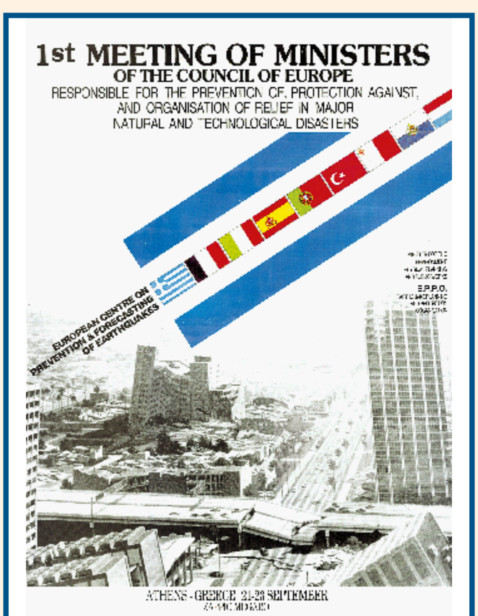
There are three levels of action within this Agreement :

- the political level with the periodical meetings of the Ministers of the Agreement and that of the Committee of Permanent Correspondents which determine the co-operation policy corresponding to the objectives;
- the scientific and technical level with:
  the "European Warning System"
  the "European Advisory Evaluation Committee for Earthquake Prediction"
  the network of "Specialised European Centres" of the Agreement ;
- the specific programmes whose characteristics differ in relation to the activities of the first two levels concerning calling upon voluntary financial contributions.

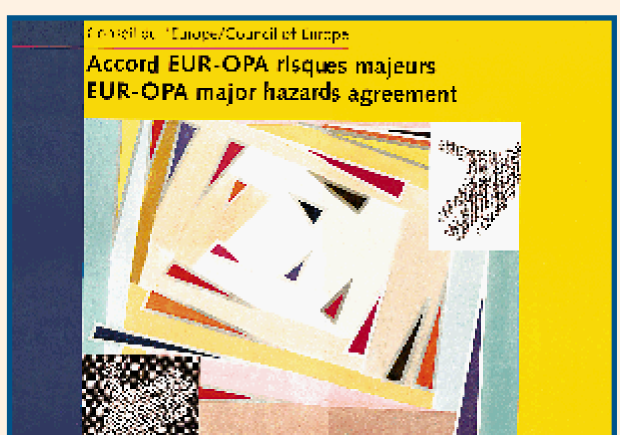
The Commission of the European Communities and UNESCO, as well as the World Health Organisation and the Department of Humanitarian Affairs of the United Nations participate in the Agreement.

Twelve Specialised Centres operate whithin the scope of the Agreement.




ATHENS 1987



# EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES (E.C.P.F.E.)

## A. OBJECTIVES of ECPFE

The European Centre on Prevention and Forecasting of Earthquakes (E.C.P.F.E.) is a non- profit organisation which operates within the framework of Council of Europe's Open Partial Agreement, in relation to European Network of Specialised Centres and it is established in Athens.

The Open Partial Agreement of the Council of Europe has been ratified by the Greek Law in 1992.

The Centre is involved in all aspects of prevention and prediction as well as in the development of practical ways of managing earthquakes. It gathers all relevant information and supports scientific approaches with a view to mitigating the consequences of earthquakes and their impact on human life.

## B. ORGANISATION of ECPFE

The Organisation of ECPFE is based upon the Administration Board and the Scientific Committee, (established accordingly by the Δ16γ/62/3/103/Γ/16-2-94 ministerial act), which are appointed by the Greek Government on the basis of the proposals put forward by the Council of Europe.

The Centre is accommodated and run at the Earthquake Planning & Protection Organisation's (EPPO) headquarters for the time being, until there is special law regulating the ECPFE.

**I**. - The **Administration Board**, consists of 7 members who make decisions concerning the Centre's activities, research programmes, as well as the budget.

Prof. D. Papanikolaou , Geologist , President of EPPO , Professor at the University of Athens, is the **President** of the A.B. of E.C.P.F.E.

**II**. -The **Scientific Committee**, consists of 17 prominent scientists. Its main task is the submission of research and educational proposals to the Administration Board.

**III.** The **Administrative Personnel** consists of the following employees of EPPO, who are appointed by the Director of EPPO :

- Director : K. Ioannidis
- Technical Assistant : A. Roditou
- Administration Secretary: Chr. Zacharia
- Economical Assistant: Har. Makri

In January 1998, the Administration Board of E.C.P.F.E. resolved to propose to the Minister of Environment and Public Works the establishment of the Centre in Kalamata, following the offer of the Mayor of the City of Kalamata. The proposed building (shown in photo) is a renovated former High School along the coastal avenue.

## C. SCIENTIFIC ACTIVITY of ECPFE for the period 1987-1997

### C1. ORGANISATION of CONFERENCES, SYMPOSIA and SEMINARS

The Centre has organised and participated in the following Seminars and Symposia.

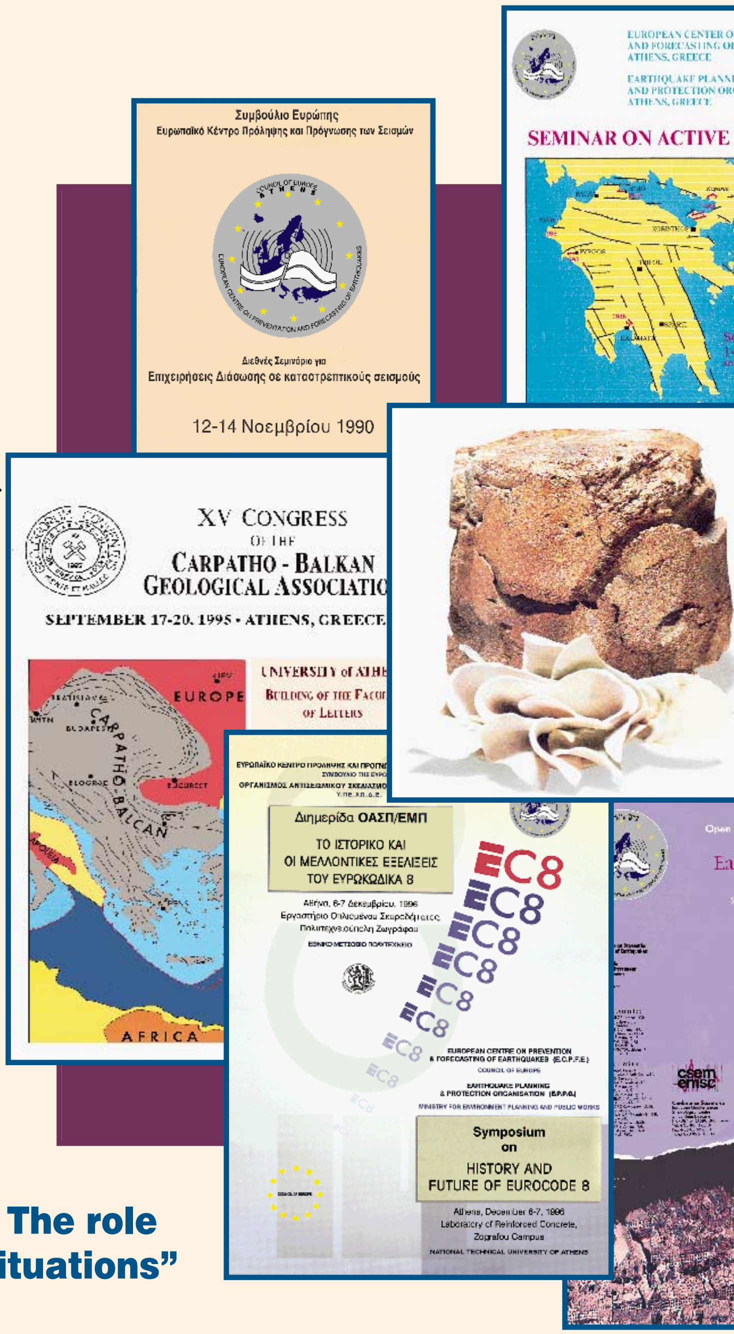
ATHENS, NOVEMBER 12-14, 1990
International Seminar on
**"Rescue Operations in Catastrophic Earthquakes"**

STRASBOURG, OCTOBER 15-18, 1991
International Conference on
**"Earthquake Prediction: State-of-the-Art"**

SANTORINI ISLAND, GREECE, THERA INSTITUTE CONVENTION CENTRE, OCTOBER 13, 1993
International Workshop on
**"Construction Techniques in Seismic Regions in Prehistoric Times"**

SANTORINI , GREECE, OCTOBER 14-16, 1993
International Seminar on
**"Historical and Monumental Structures in Seismic Regions"**

ATHENS, MAY 4-7, 1995
European Symposium on
**"Natural and Technological Disasters : The role of Women in Emergency Situations"**




ATHENS, MAY 15, 1995
**A one-day Seminar** concerning
**"The Dramatic Earthquake Disaster in Kobe"**

ATHENS, SEPTEMBER 17-20, 1995
Symposium on
**"Seismicity of the Carpatho-Balkan Region"**

ATHENS, THE PELOPONNESE, SEPTEMBER 13-17, 1995
**"Seminar on Active Faults"**

ATHENS, DECEMBER 6-7, 1996
The Symposium on
**"History and Future of Eurocode 8"**

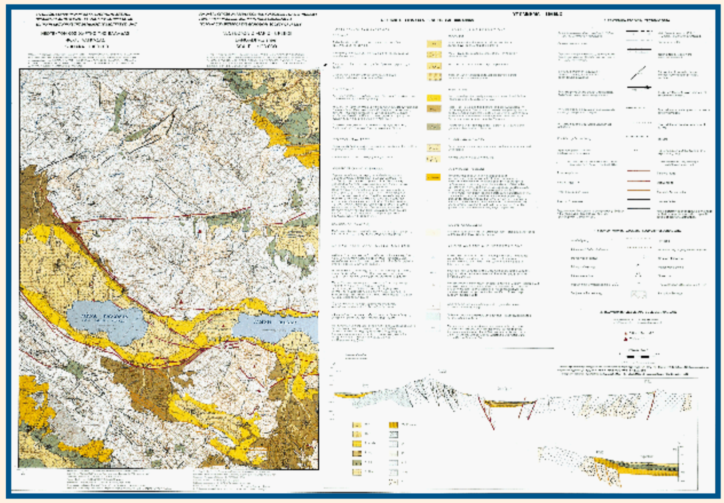
ATHENS, DECEMBER 12-14, 1996
**"International Workshop on the Research Programmes for Prevention and Forecasting of Earthquakes"**

## C2. RESEARCH PROJECTS of ECPFE for the period 1987 - 1997

The ECPFE has undertaken a variety of research projects including: earthquake prediction research and studies on the seismic response of structures and their improvement of earthquake resistance design. Also two Pilot Studies on Emergency Planning for earthquake disaster in urban areas at the municipal level have been completed.
More specifically, the following scientific programmes have already been carried out:

1. **"Multidisciplinary study of earthquake precursors at the eastern part of Central Greece (Thessalia)**
   20.1.92 - 11.4.94
   Sc. Cord.: E.E. Papadimitriou, Univ. of Tessaloniki.
2. **"Analysis of existing recordings of the earth's electric field for the detection of long period variations as earthquake precursors"**
   20.1.92 - 7.12.94
   Sc. Cord.: A.Tselentis, Ass.Prof. Univ.of Patras, G.Ikonomou Lect., A. Ifantis
3. **"Study of the influence of infill walls in the seismic response of buildings and proposals for the improvement of their response"**
   20.1.92 - 20.2.96
   Sc. Cord.: P.Karydis, Prof. of Earthquake Eng., Nat. Techn. Univ. of Athens.
4. **"Seismic Behaviour & Design of Masonry Buildings & Infilled Reinforced Concrete Frames"**
   20.1.92 - 9.8.95
   By: Prof. M. N. Fardis, Univ. of Patras
   Prof. E. Vintzileou, Nat. Techn. Univ. of Athens
5. **Pilot study: Earthquake emergency plan for the Municipality of Athens.**
   **"Emergency Operation Plan against Seismic Disasters for the Municipality of Athens"**
   30.12.94 - 10.1.97
   Sc. Cord.:L.Vassenhoven, Prof. of Urban and Regional Planning, Nat.Techn.Univ. of Athens-
6. **"Torsional ground motion of the base and torsional response of buildings"**
   14.4.95 - 17.9.97
   Sc. Cord.: E. Mitsopoulou, PhD. Civil Eng., Prof. of Aristotle Univ. of Thessaloniki-
7. **"Earthquake behaviour of ancient classic and Hellenistic monumental structures - Preliminary study of ancient monuments of Macedonia and Thrace"**
   1.5.95, Project in progress.
   Completion date of the Project :
   By : George C. Manos, Professor, Dept. of Civil Engineering of Aristotle University of Thessaloniki.
8. **"Stress assessment from seismic tomographic measurements"**
   2.5. 95 - 12.9.97
   By Prof. A. Tselentis, Seismologist- P. Tsarpalis - D.Paliatsas, MsSc. Eng.Geophysics
   Coordinator of the Project : K. Grivas, Geologist
9. **"Geological-Geotectonic-Neotectonics Research on Archaeological Sites and Monuments"**
   Minoan Palace of Kato Zakros -Mycenae
   1.6.95, Project in progress.
   Sc. Cord.: Prof. I. Mariolakos, University of Athens.
10. **"Criteria for the evaluation of Local Soil Effects on Seismic Motions"**
    20.7.95 - 24.3.97
    Sc. Cord.: G.D.Boukovalas, Ass.Prof.of Nat. Tech.Univ. of Athens.
11. **"Operational Emergency Plan for the Municipality of Heraklion in Response to Seismic Disaster Situations"**
    23.10.95 - 23.6.97
    Sc. Cord.: P.M. Delladetsimas, Senior Lecturer Univ. of the Aegean.
12. **"Eurocode 8 in the form of Expert System"**
    20.11.96, Project in progress
    Sc. Cord.: V.Koumousis.

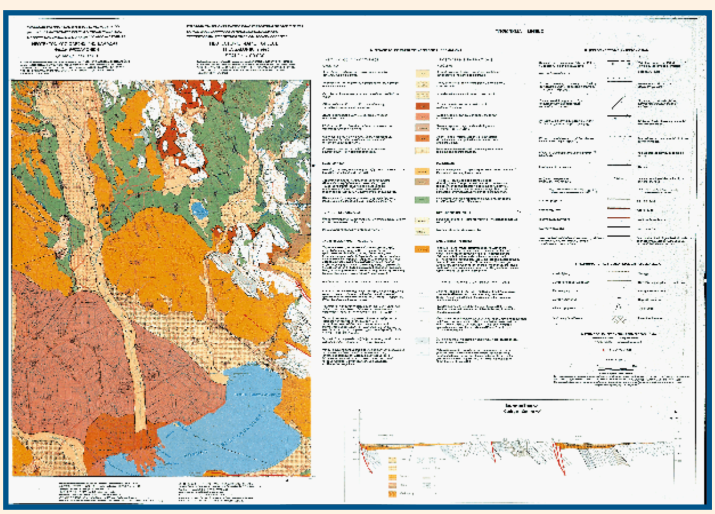
## C3. NEOTECTONIC MAPS



**"Langadha Sheet"**

**1996**

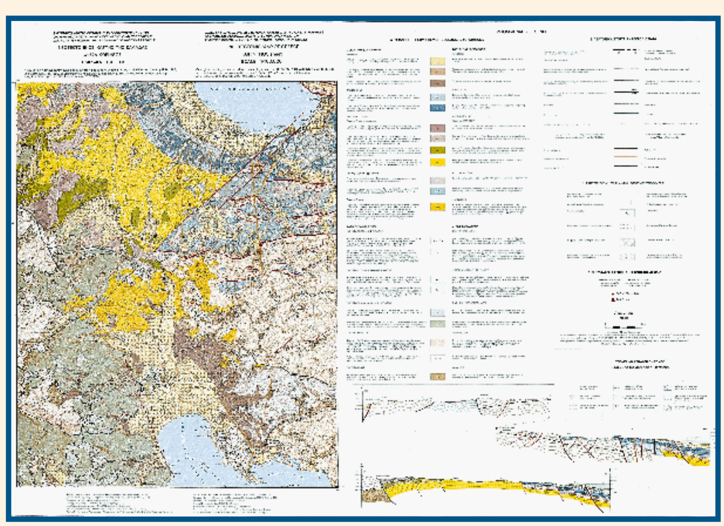
Sc. Cord.: Prof. D. Mountrakis, University of Thessaloniki.



**"Thessaloniki Sheet"**

**1996**

Sc. Cord.: Prof. D. Mountrakis, University of Thessaloniki.



**"Korinthos Sheet"**

**1996**

Sc. Cord.: Prof. D.J. Papanikolaou, University of Athens

## D. SCIENTIFIC ACTIVITIES of E.C.P.F.E. for the year 1998

### D1. ORGANISATION of CONFERENCES, SYMPOSIA and SEMINARS

#### 1. "The 8th Congress of the Geological Society of Greece"

At the 8th Congress of the Geological Society of Greece, held in Patra, May 1998, Professor D. J. Papanikolaou was invited to present a keynote address at the general assembly of the Congress on the first results of the main project of E.C.P.F.E. The title of the 45 minutes presentation was «Multidisciplinary monitoring of active geodynamic environments: the Nisyros case».

#### 2. Proceedings of the «Seminar on Active Faults»

**Formalization of Neotectonics Maps**

Report of activities during the International Workshop on Formalization of Neotectonics Maps (Patra, Greece, 29 May - 2 June 1998)

The International Workshop on Formalization of Neotectonic Maps organized by the Working Group I of the INQUA Neotectonics Commission was held in the framework of the 8th Congress of the Geological Society of Greece (Patra, Peloponnesus 29 May - 2 June 1998). It was supported and sponsored by the European Centre on Prevention and Forecasting of Earthquakes (ECPFE), Earthquake Planning & Protection Organization (EPPO), Geological Society of Greece, University of Athens, Ministries of Culture and Development of Greece, and the private companies Dioryga Corinthou S.A. and Geyfra S.A.

Geologists of mainly European countries attended the International workshop. The number of participants in the one - day session (29/5/98) was around forty persons with representation from Poland, France, Germany, Italy, Israel, Russia, Norway, Spain and Greece.

At the beginning of the morning session Professors Dimitrios Papanikolaou (President of EPPO and ECPFE), Carlo Bartolini (President of the INQUA NC), Ilias Mariolakos (Coordinator of WGI of the INQUA N.C.), gave the Welcome Address. After a theoretical dissertation by C. Bartolini about the utility - no utility of neotectonic maps and other related graphic documents, several oral presentations mainly concerning to neotectonic mapping and data from France, Greece, Norway, Poland and Russia were given.

The Spanish working - group (Jos L. Goy, P.G. Silva, Univ. Salamanca; Cari Zazo, CSIC, Madrid; and Teresa Bardaji, Univ. Alcala de Henares) opened the afternoon session presenting different scales Neotectonic Maps of the Gibraltar Strait and SE Spain (Murcia and Almeria). P.G. Silva presented the main criteria followed for the development of the 1:100.000 Neotectonic Map of the Gibraltar Strait: Quaternary stratigraphy, Geomorphology, Tectonics and Seismicity. Professors I. Mariolakos and P.G. Silva presented the Questionnaire for the Formalization of Neotectonic Maps and gave the first preliminary results on the basis of the first 37 answers to the 350 questionnaires sent all over the world.

The proposed questionnaire became the main topic of the workshop and an open discussion between the different persons attending the event took place. The discussion was focused in three main tasks: 1) Neotectonic maps graphic scales (NMGS); 2) Neotectonic Period time-scales (NP Onset), and 3) the concept of seismic, seismogenic and active faults.

A four days field trip took place from 30/5/98 to 2/6/98 in Peloponnesus and Sterea Hellas with several stops.

## D2. RESEARCH PROJECTS of ECPFE

During 1997-1998 the main research activity of the centre was the multidisciplinany project:
**"Monitoring of Seismic Activity along the Aegean Volcanic Arc: with focus on the eastern part of the arc in Kos and mainly Nisyros Islands".**
The focus on Nisyros island resulted as a priority after the 1996 earthquakes, which destroyed several houses at Mandraki, the capital of Nisyros. It is remarkable that another seismic activity, with hundreds of houses damaged, along the Aegean Volcanic Arc had occured on the island of Milos in 1992.
This Newsletter No 2 includes a progress report of this multidisciplinary project, containing mainly the basic new data. Some parts of this project have been presented at the following congresses and conferences by members of the scientific groups participating in the project.
**1. "Multidisciplinary monitoring of active geodynamic environments: the Nisyros case".**
Presented by the coordinator of the project Prof. D. Papanikolaou, as a keynote address at the 8th Congress of the Geological Society of Greece in Patra, May 1998.
**2. "Surveillance of Nisyros Volcano: Establishment and remeasurement of G.P.S. and radon networks"**, by E. Lagios, S. Chailas, I. Giannopoulos and P. Sotiropoulos presented at the 8th Congress of the Geological Society of Greece, Patra, May 1998.
**3. "Volcanism and crustal deformation of Nisyros - East Aegean Sea"**, by T. Chonia, J. Makris, S. Nikolova, D. Papanikolaou and J. Papoulia presented at the 26th Assembly of the European Seismological Commission, in Tel - Aviv, Israel, on August 1998.
**4. "Morphotectonics of Kos island Dodekanese, Greece"**, by D. Papanikolaou and P. Nomikou presented at the 15th Congress of the Carpatho - Balcan Geological Association, in Vienna, August, 1998.
**5. "Active and Passive seismic studies of Nisyros Volcano - East Aegean Sea"**, by J. Makris, T. Chonia, D. Papanikolaou and G. Stavrakakis presented at the 3rd Conference on the Geology of East Mediterranean, in Cyprus, September, 1998.
**6. "Active Geodynamics at Nisyros, the eastern edge of the Aegean Volcanic Arc"**, by P. Nomikou and D. Papanikolaou, presented at the 3rd Conference on the Geology of East Mediterranean, in Cyprus, Sept., 1998.

The participating scientific groups of the multidisciplinary project are shown on the following table:

**«Multidisciplinary monitoring of active geodynamic enviroments: the Nisyros case»**
**Project coordinator Prof. D. Papanikolaou.**

| | Subject | Scientific Institute | Scientific Leader |
|---|---|---|---|
| Onshore Studies | 1) Geology of the islands Kos and Nisyros | • University of Athens, Div. Dynamic Tectonic Applied Geology | Prof. D. Papanikolaou |
| Onshore Studies | 2) Neotectonics on land | • University of Athens, Div. Dynamic Tectonic Applied Geology | Prof. D. Papanikolaou |
| Onshore Studies | 3) Seismology, on land observations | • Geodynamic Institute, National Observatory of Athens<br>• University of Hamburg, Laboratory of Geophysics<br>• Earthquake Planning and Protection Organization | Dr G. Stavrakakis<br>Prof. J. Makris<br>Dr Ch. Metaxas |
| Onshore Studies | 4) Geodetic Measurements with G.P.S. and Radon Measurement | • University of Athens, Division of Geophysics and Geothermy | Assoc.Prof. E. Lagios |
| Onshore Studies | 5) Satelite images | • E.P.P.O. | Dr I. Parcharidis |
| Onshore Studies | 6) Damages on buildings | • E.P.P.O. | K. Ioannidis |
| | 7) Measurements of Noble gases | • ETH Zurich, Dept. of Earth Sciences | Prof. V. Dietrich |
| Offshore Studies | 8) Submarine Geology and Neotectonics | • National Center for Marine Research<br>• University of Athens, Div. Dynamic Tectonic Applied Geology | Dr V. Lykousis<br>Prof. D. Papanikolaou |
| Offshore Studies | 9) Deep Submarine Crustal Structure | • University of Hamburg, Laboratory of Geophysics | Prof. J. Makris |
| Offshore Studies | 10) Submarine Seismicity | • University of Hamburg Laboratory of Geophysics<br>• National Center for Marine Research | Prof. J. Makris<br>Dr J. Papoulia |

## 1. The geotectonic position of Nisyros within the Hellenic Arc *(D. J. Papanikolaou)*

The present day geodynamic structure of the Hellenic Arc, as shown schematically in Fig. 1.1, includes the Aegean Volcanic arc behind the back-arc mollasic basin of the Cretan Sea and the parallel, more external, structures of the Peloponnesus - Crete - Dodekanese island arc and the Hellenic trenches, along the forearc basin in the Ionian and Libyan Seas. The subduction of the East Mediterranean lithosphere below the Hellenic Arc reaches a depth of approximately 200 Km below the present day volcanic arc, outcropping mainly on the islands of Milos, Thira, Kos and Nisyros (Fig. 1.2).

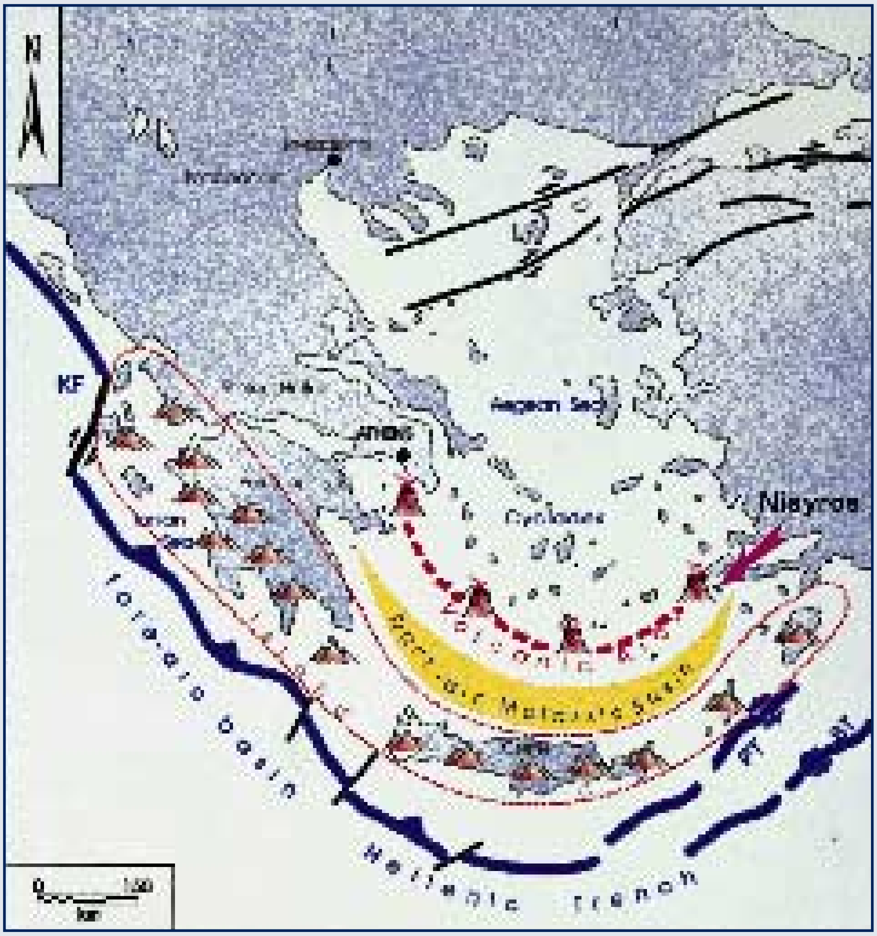



*Fig. 1.1*

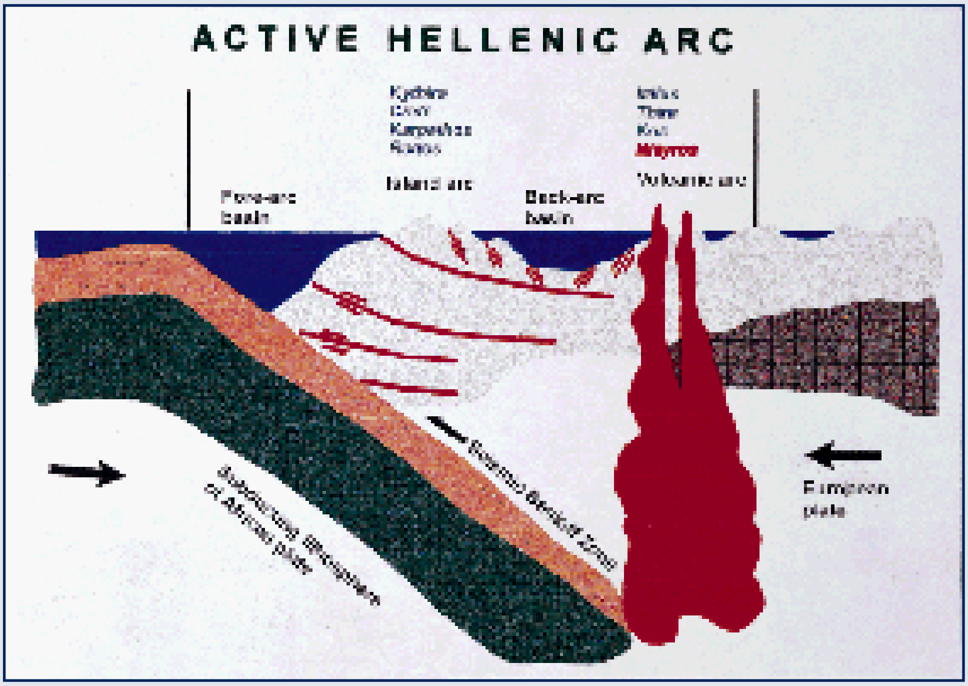



*Fig. 1.2*

## 2. The Nisyros Volcano *(D. J. Papanikolaou and collaborators)*

The entire Nisyros Island is composed of Quaternary volcanic rocks, which include a first stratovolcano type sequence of lavas and pyroclastics (A,B,C,D), followed by the rhyolites of Nikia (Fig. 2.1), which all together constitute the first period of the Nisyros volcano building process with the formation of the caldera. The second period of Nisyros volcanism includes the massive extrusions of the dacitic lavas of Prof. Ilias.

No major volcanic eruption is known during the historical period on Nisyros. Only some phreatic explosions are known in 1422, 1830, 1871, 1873 and 1888 within the remnant of the caldera in the area of the present day occurring volcanic craters. The main volcanic activity of Nisyros during this century is the numerous thermal springs occurring mainly along the northern coasts and the emissions of gasses within the craters of the caldera.

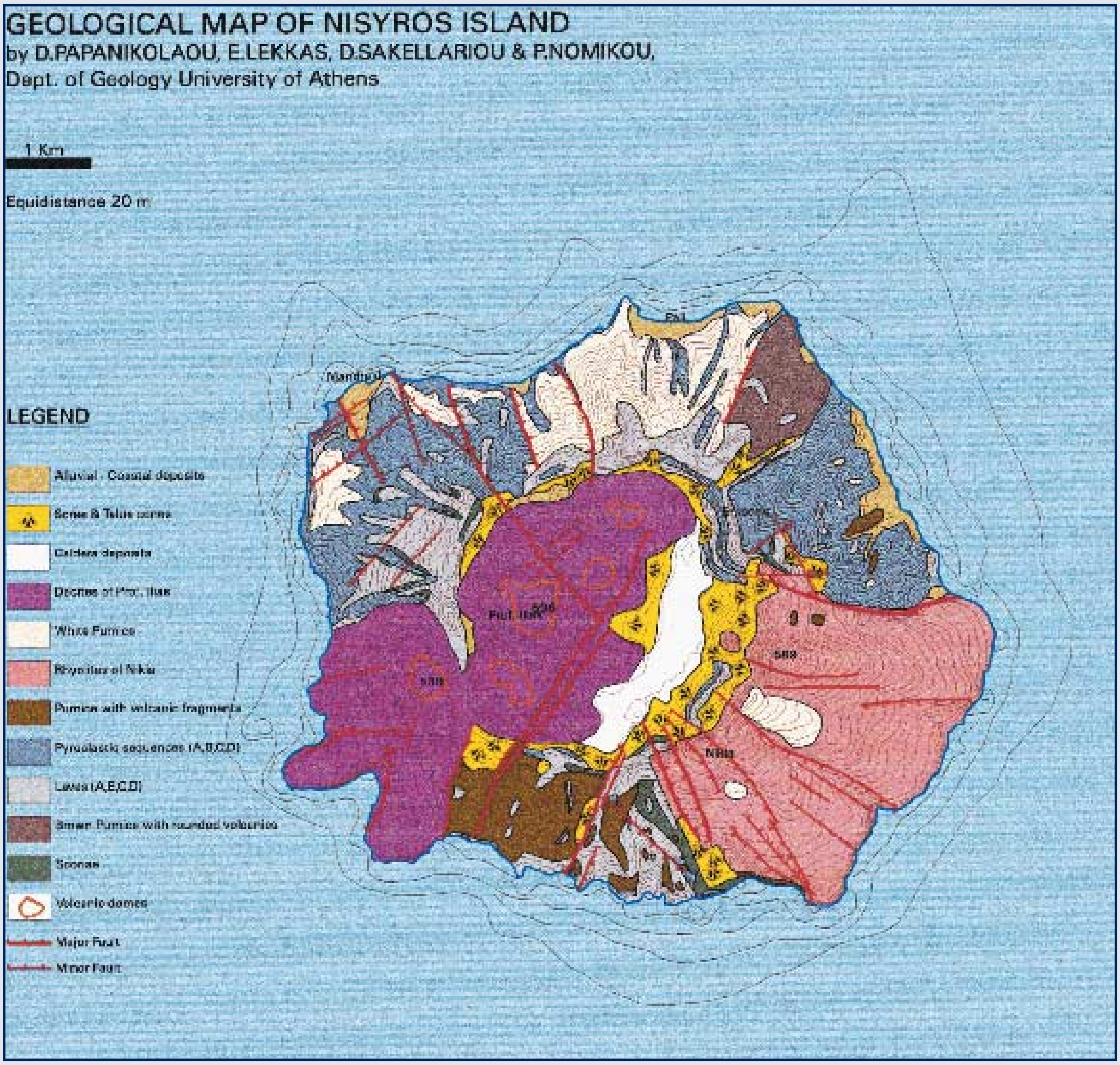



*Fig. 2.1*

Several active faults have been mapped on Nisyros, shown on the morphotectonic map of Fig. 2.2. The fault throw is about 100 m. in some cases of major faults and a few decades of m. in the minor faults. A zone of scree is developed around the caldera and several planar surfaces are observed dipping in a radial manner from the caldera rim downwards to the circular coast.

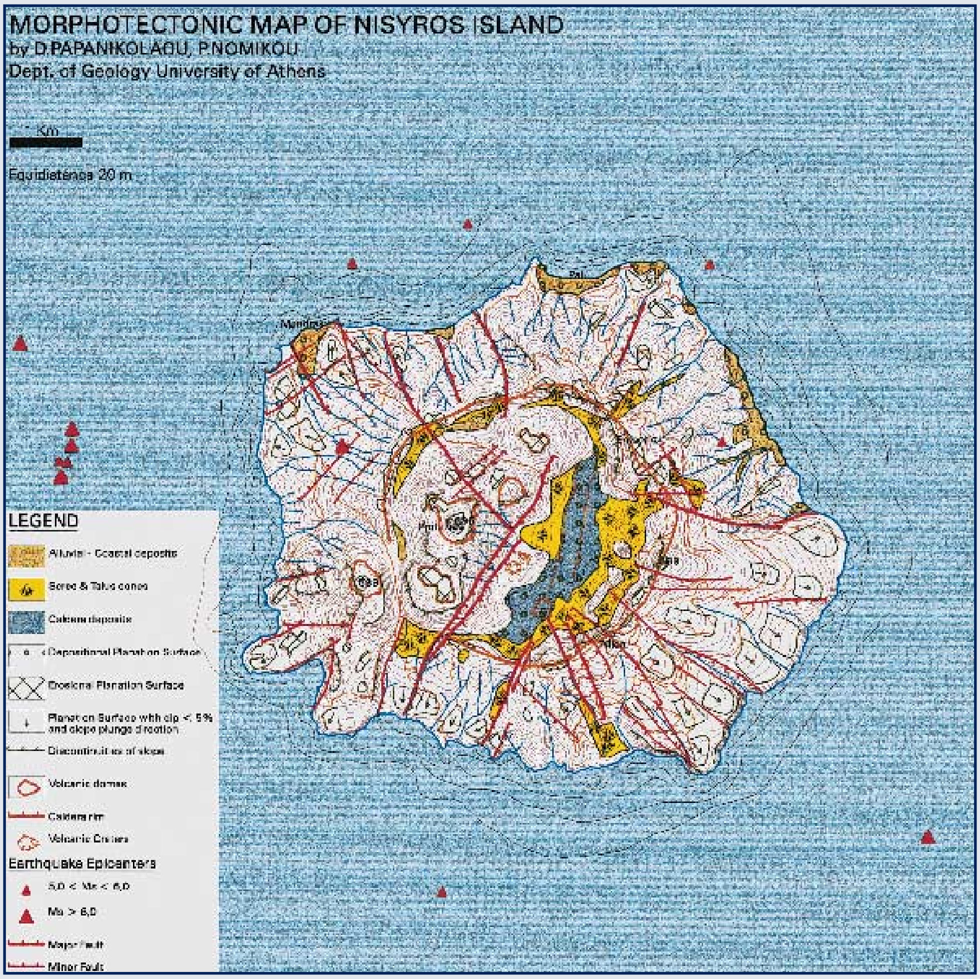



*Fig. 2.2*

### 3. Seismicity of Nisyros *(G. Stavrakakis, I. Papoulia)*

The only major destructive earthquake of this century on Nisyros island occurred in 1933, with extended damage especially at the Emborio village, situated on the eastern flanks of the Nisyros volcano, which was semi-abandoned.

In 1996 an earthquake activity started with earthquake magnitudes between 4 and 5 R scale, which in July 1996 damaged about 30 houses in the western part of Mandraki. The damaged houses occur all along a narrow street along a valley developed parallel to the hill of Panaghia Spiliani Monastery and former Venetian castle, which is following a NNW-SSE fault. The fractures have been observed also on the stairs of the small roads between the houses and could be followed down to the coastline. The continuation of the fault towards the north under the sea water is evident.

The diagrammes of Fig. 3.1 a, b, c, d, show the seismicity around Nisyros, before the beggining of the seismic activity (1995) up to May 1998. Fig. 3.2 and Fig. 3.3 show the overall seismicity, recorded in the area and especially the data obtained by the established on land mobile seismological network.

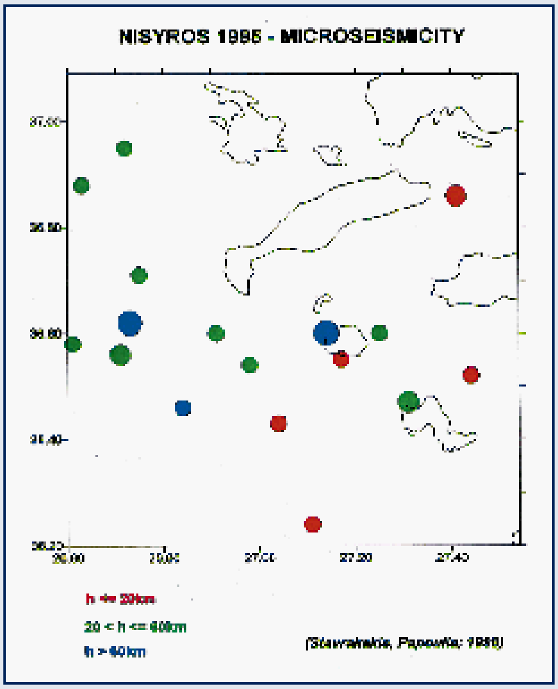



Fig. 3.1a

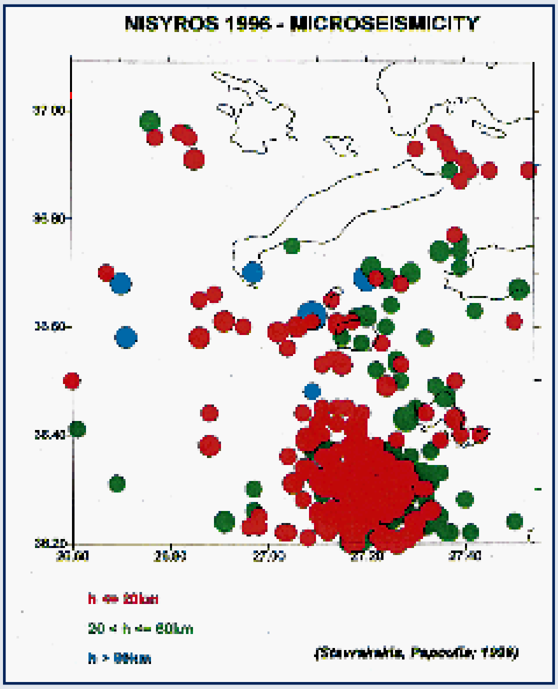



Fig. 3.1b

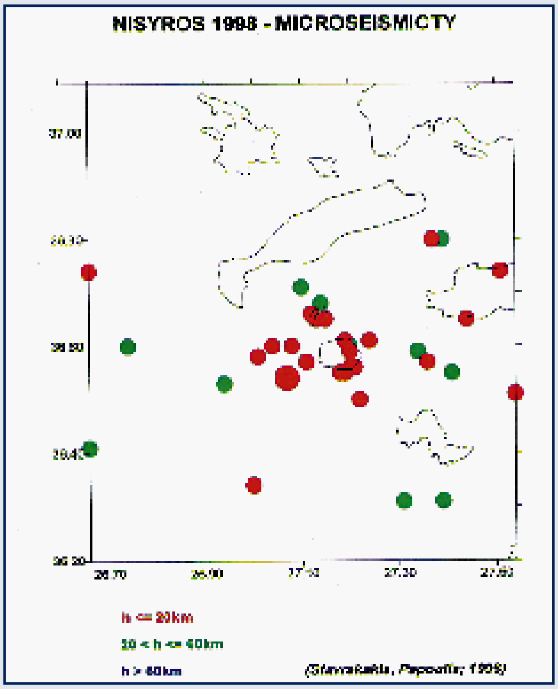



Fig. 3.1c

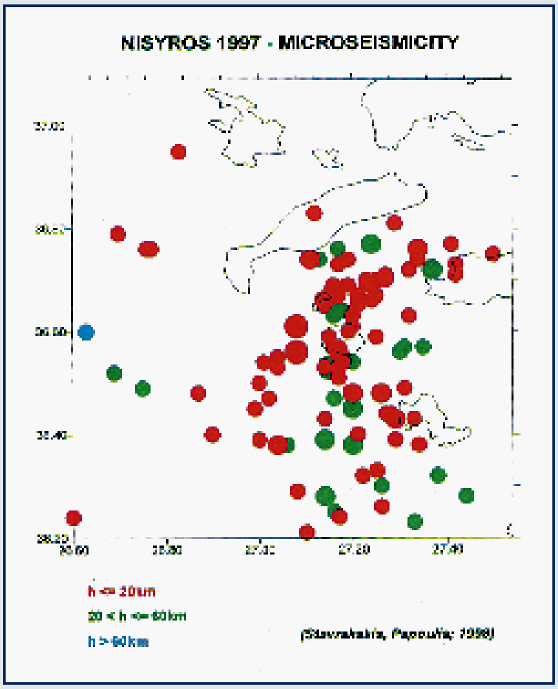



Fig. 3.1d

Fig. 3.1

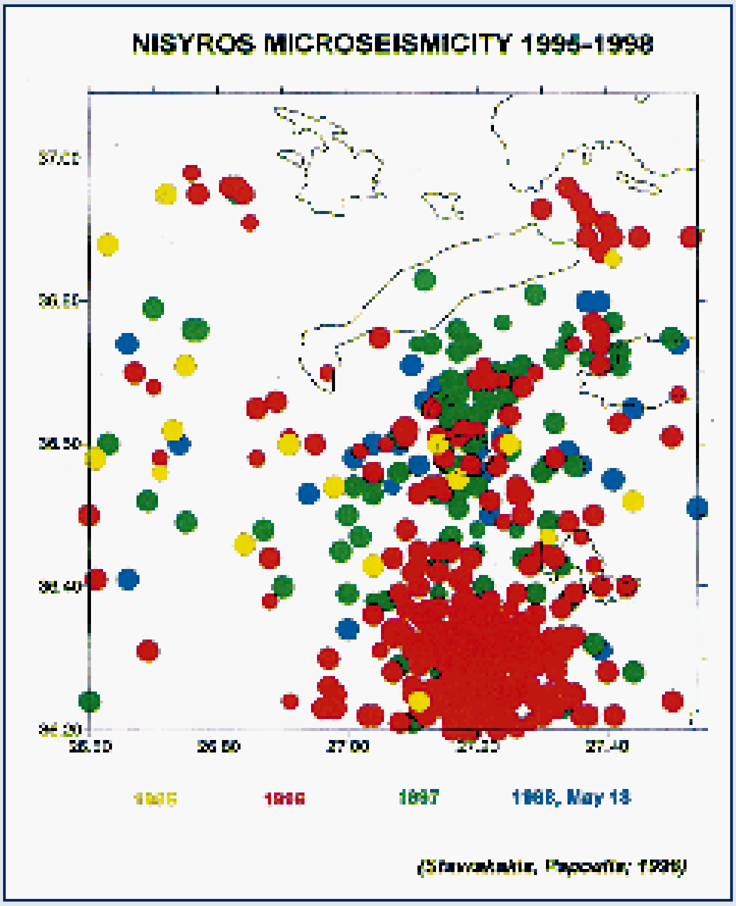



Fig. 3.2

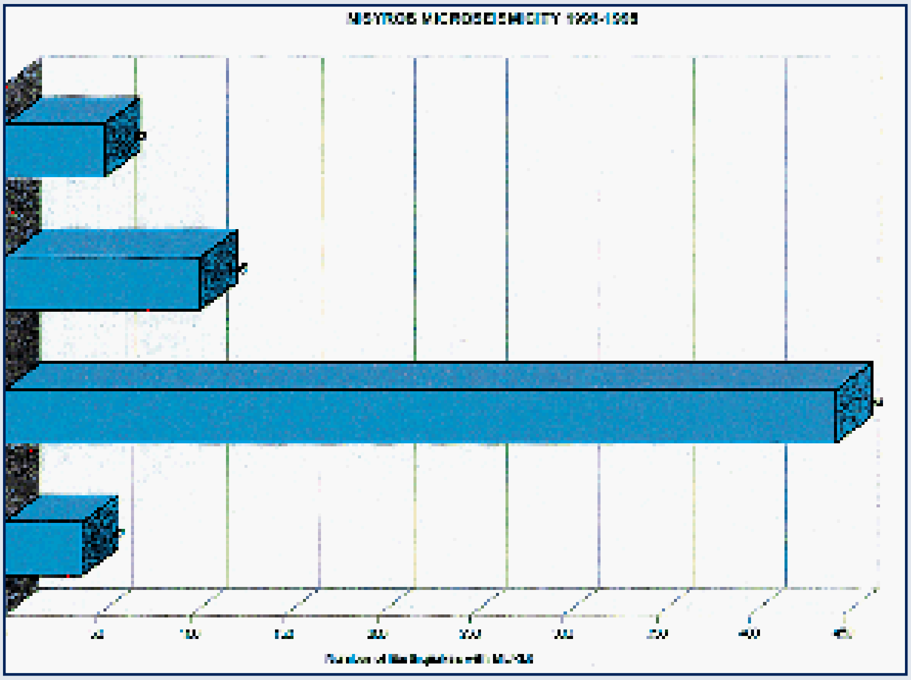


Fig. 3.3

## 4. Volcanic landslides *(P. Nomikou, D. J. Papanikolaou)*

In August 1997 the seismic activity became more important with some events between 4,5 and 5,5 R scale. During the earthquake of August 7th 1997 important landslides occurred within the Polyvotis volcanic crater of Nisyros (Fig. 4.1) destroying the top of the volcanic cliffs.

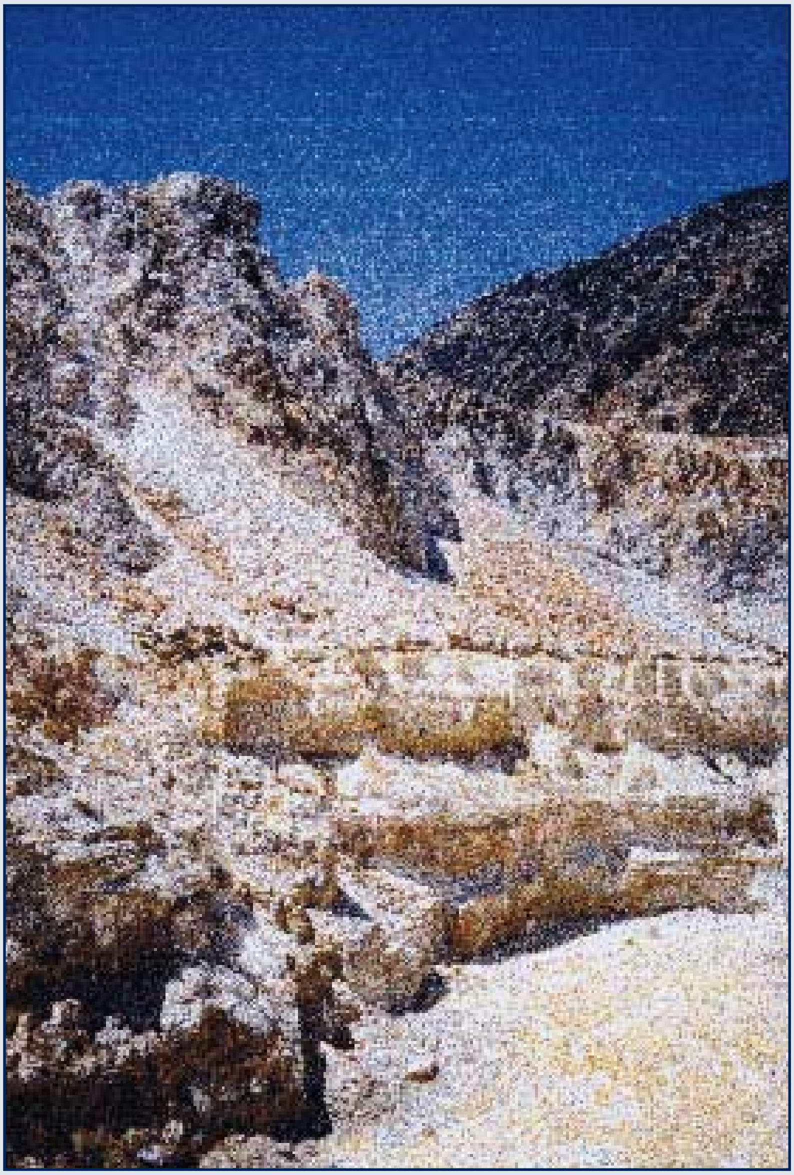


*Fig. 4.1*

### 5. Deep Geophysical Survey *(J. Makris and collaborators)*

In October 1997 an active and passive seismic experiment was conducted along a profile extending for 140 km from the island of Chalki to the island of Leros crossing the volcanoes of Nisyros, Yali and Cos (Fig. 5.1).

For the active seismic experiment, 20 Ocean Bottom Seismographs and 20 Landstations were deployed and recorded 1023 shots fired by a tunned 48 liter airgun array at 120 m. intervals.

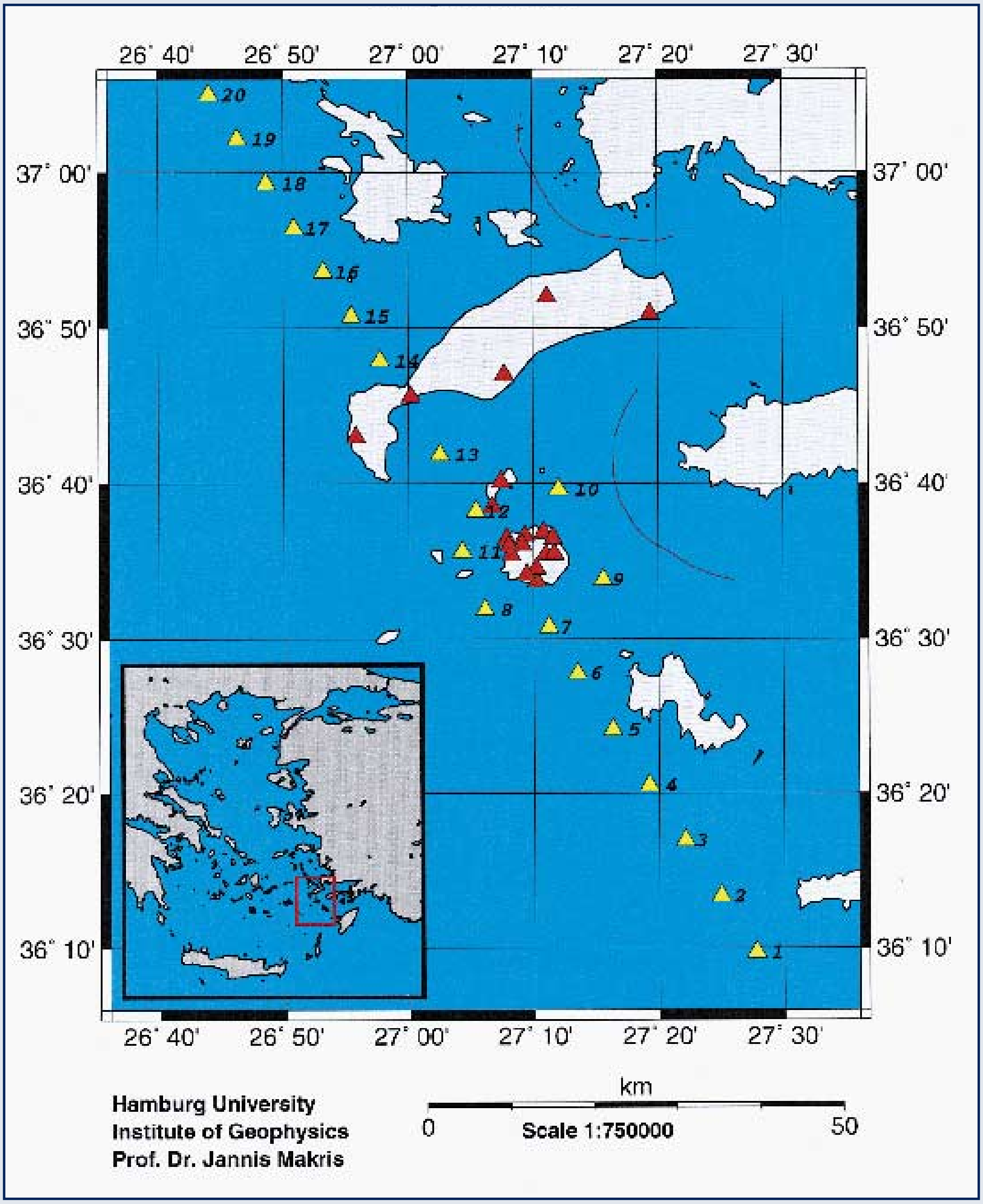



*Fig. 5.1*

The seismicity study was accomplished by deploying 22, 3-components, digital stations onshore. It showed that the activity within the caldera is high, ranging from 17 to 30 events per day. The locations of 1200 hypocentres indicate that a fault system between Mandraki (Nisyros) and Yali is extremely active and that this system is truncated by an east north - east oriented fault. The hypocenters are located at the upper crustal section and mostly at depths lss than 10 kms (Fig. 5.2).

**Nisyros 1997 - Microseismicity**

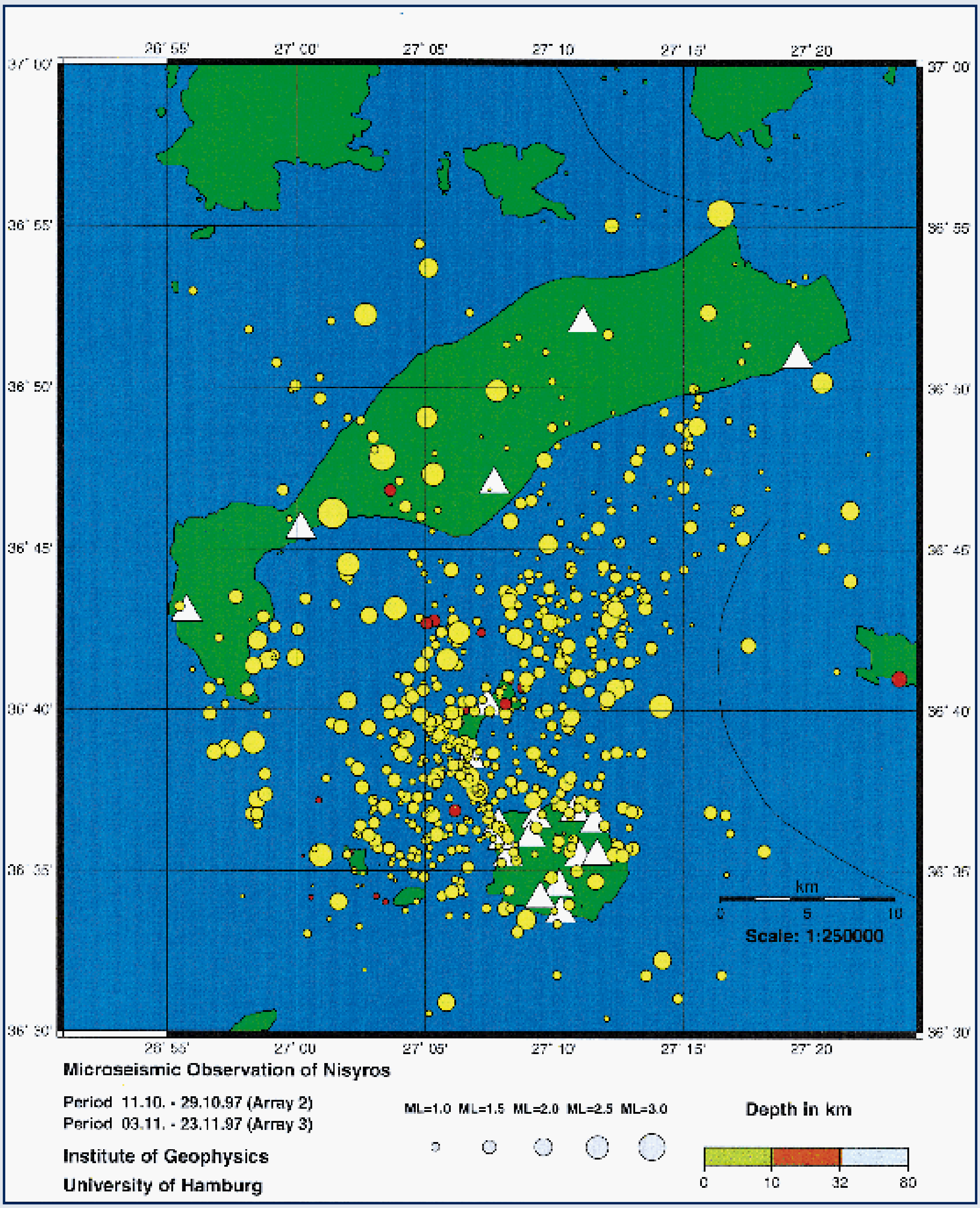



*Fig. 5.2*

**Nisyros area. First - arrival inversion. Preliminary result.**

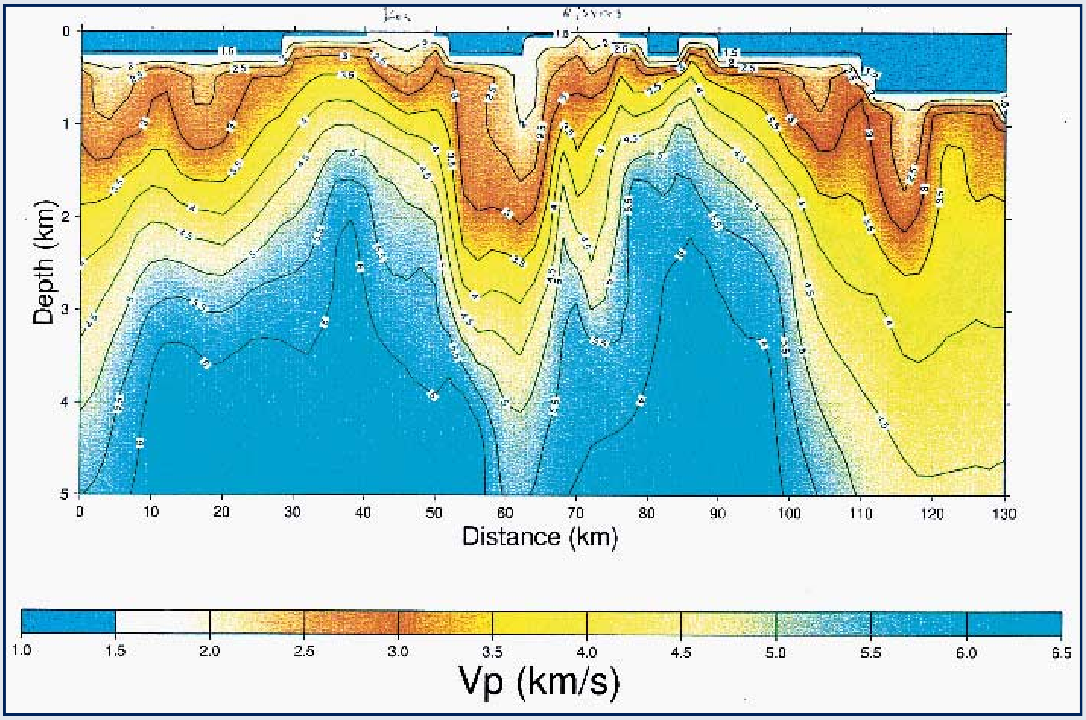



*Fig. 5.3*

Profile across the NNW-SSE line of Ocean Bottom Seismographs shown on Fig. 5.3 above.

The final model for the velocity structure below Nisyros shows that the energy penetrated up to 7 km in depth and mapped a volcanic intrusion. The shallowest penetration depth of this magma is only 1.8 km below surface. With increasing depth the intrusion widens and covers a wider part of the volcano. In summary: The shallow depth of the intruded magma has elevated the isotherms below the volcano significantly, so that the aquifers above the intrusion have reached a mean temperature of 270° C. If the high seismic activity prevailing at present would fracture and open the overlying lithological units, the overheated aquifers could react explosively as was the case in 1873. (fig. 5.4 a, b, c, d).

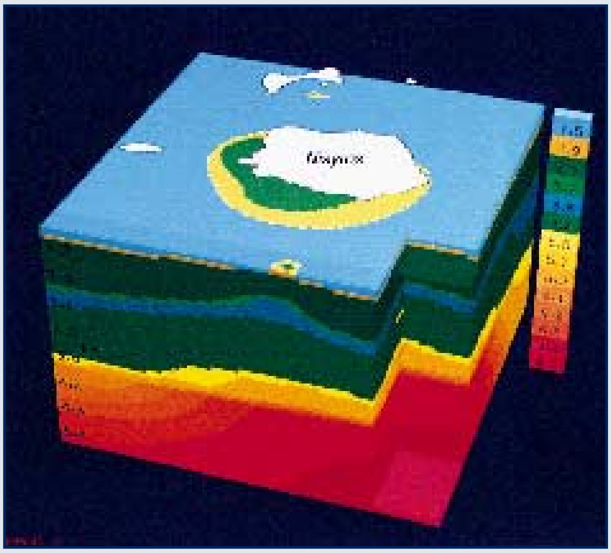


Fig. 5.4a

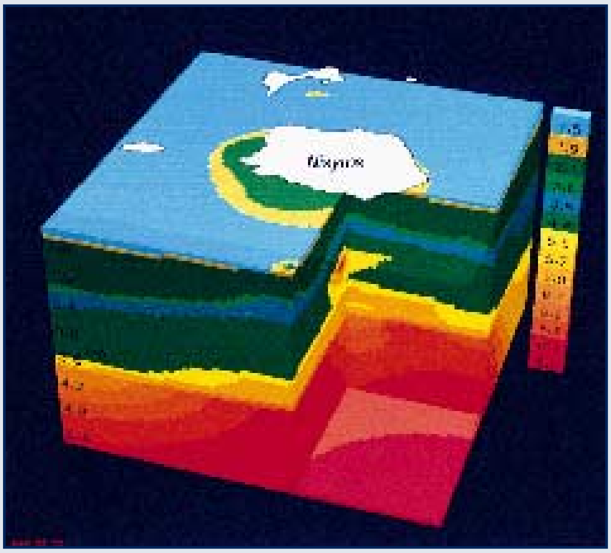


Fig. 5.4b

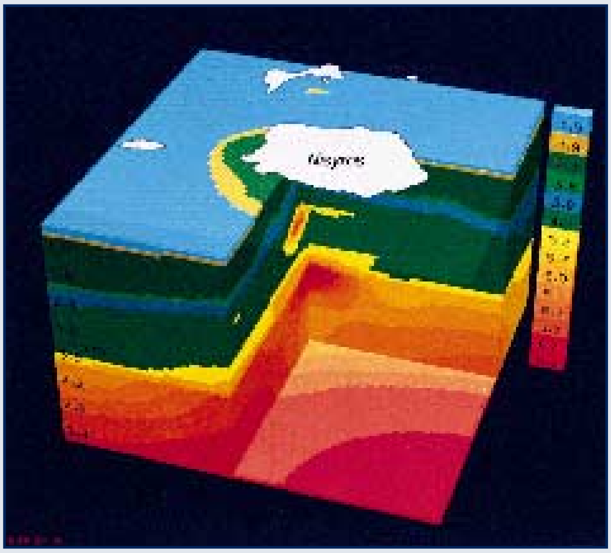


Fig. 5.4c

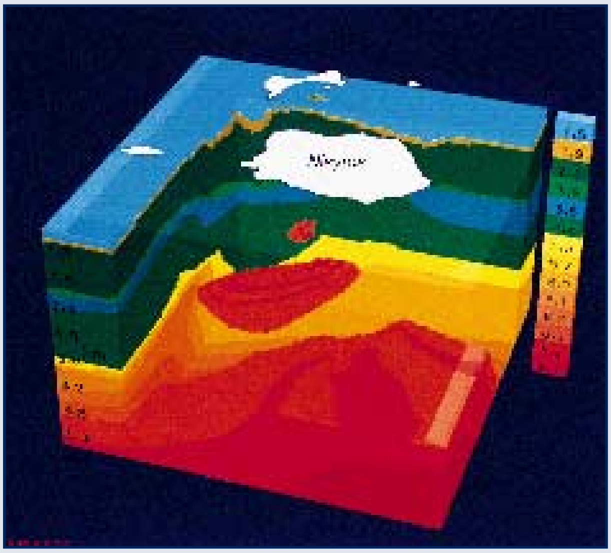
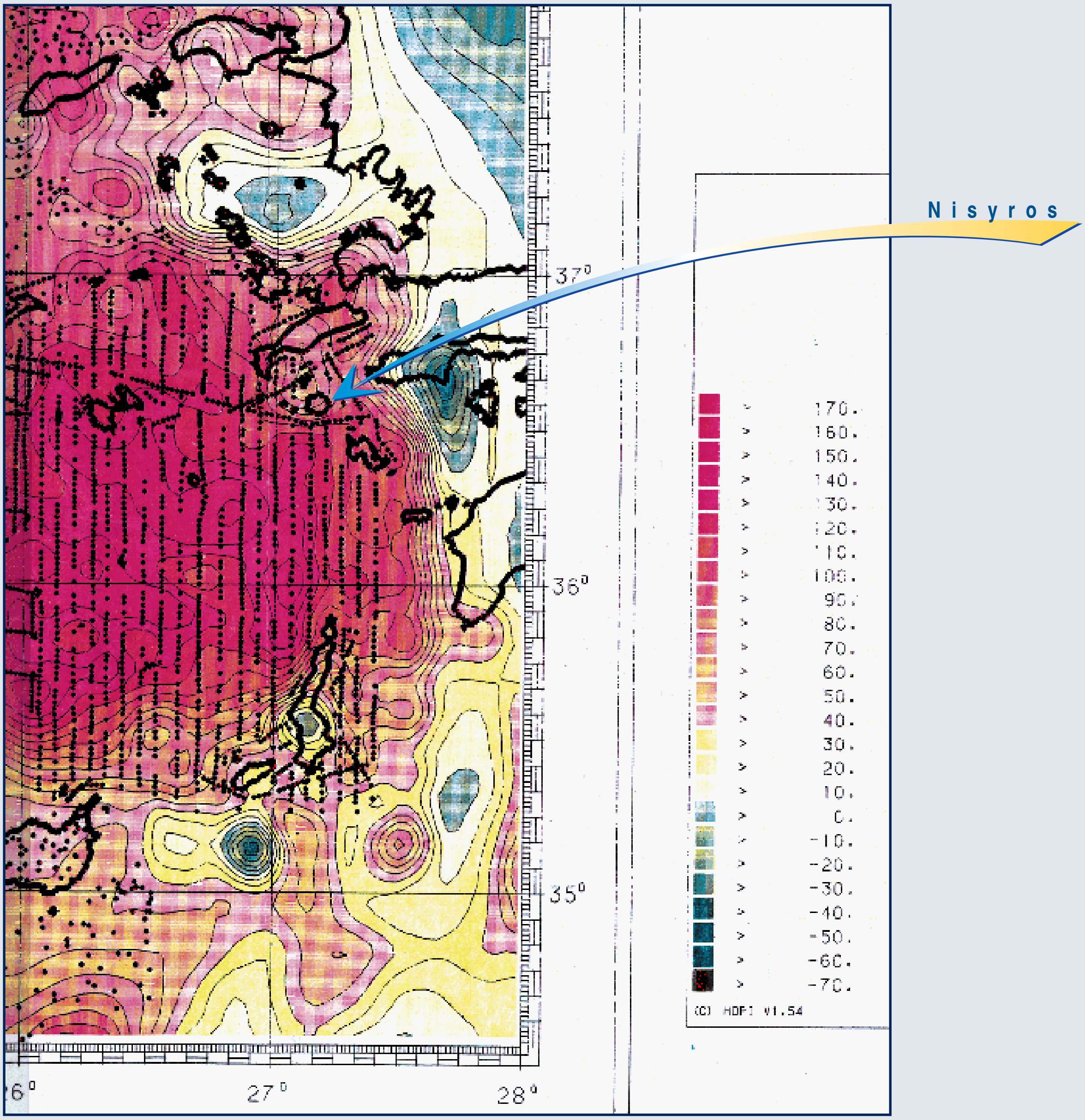


Fig. 5.4d

Fig. 5.4

### Gravimetric data




*The gravity amomaly in the area between Kos and Nisyros shown on the regional gravimetric map of J. Makris and collaborators.*

## 6. Submarine Reconnaisance *(D. J. Papanikolaou, P. Nomikou, V. Lykousis)*

A systematic survey in the submarine area between Nisyros and Kos islands has been overtaken with two cruises: the first in October 1997, using the research vessel "ISKATEL" and the second in April 1998, using the research vessel "AEGAIO" of the National Center for Marine Research. The preliminary interpretation of the submarine data permitted the compilation of the geological map shown of Fig. 6.1, which includes the geological structure of the islands of Kos and Nisyros together with the adjacent submarine area. More detailed analysis has been carried out in the submarine area of the Yali - Nisyros channel whose simplified map is shown on Fig. 6.2.

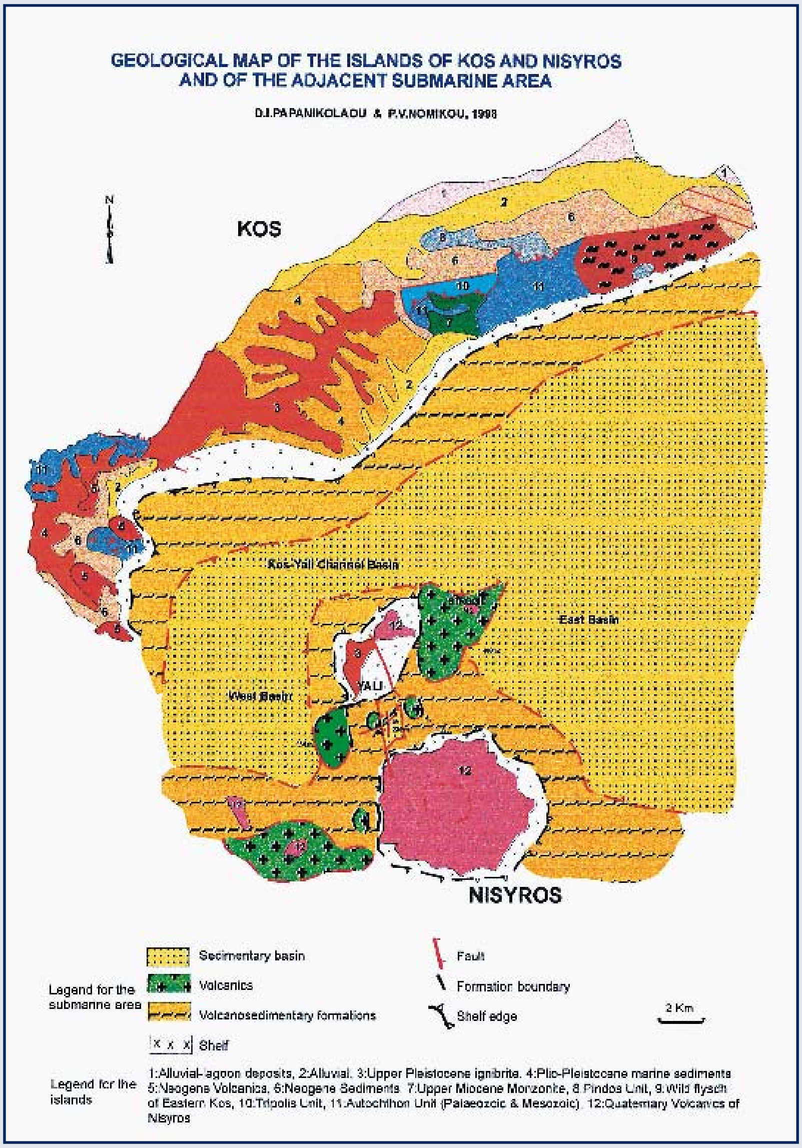



*Fig. 6.1*

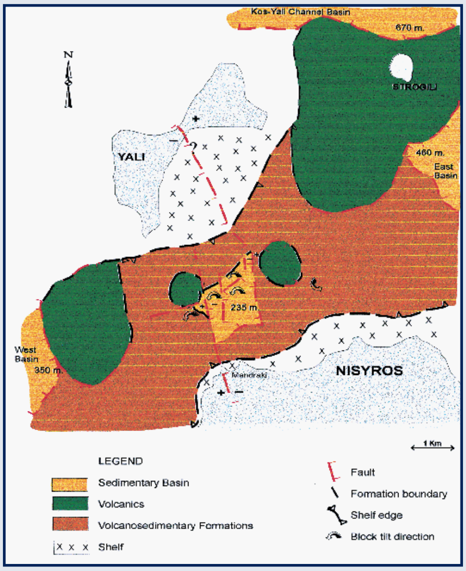



*Fig. 6.2*

The first results of this study have shown:

I) The existence of important submarine faults in the area. The most important submarine fault corresponds to the northern prolongation of the N-S fault of Mandraki, shown on photo 6.1, whose activation caused the observed damage in the houses.

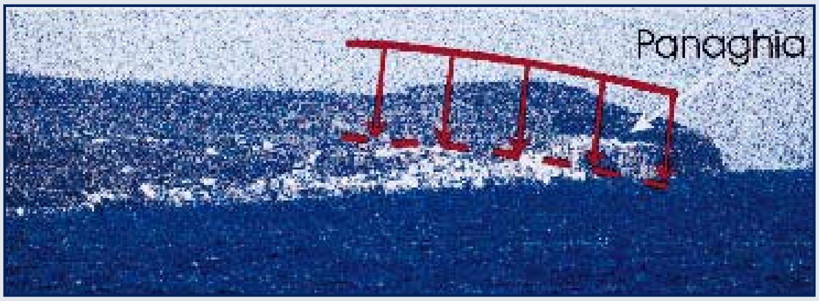



*Photo 6.1*

The fault throw is estimated at 100 m. As shown on the representative profile of Fig. 6.3. The fault length is estimated at approximately 5 km.

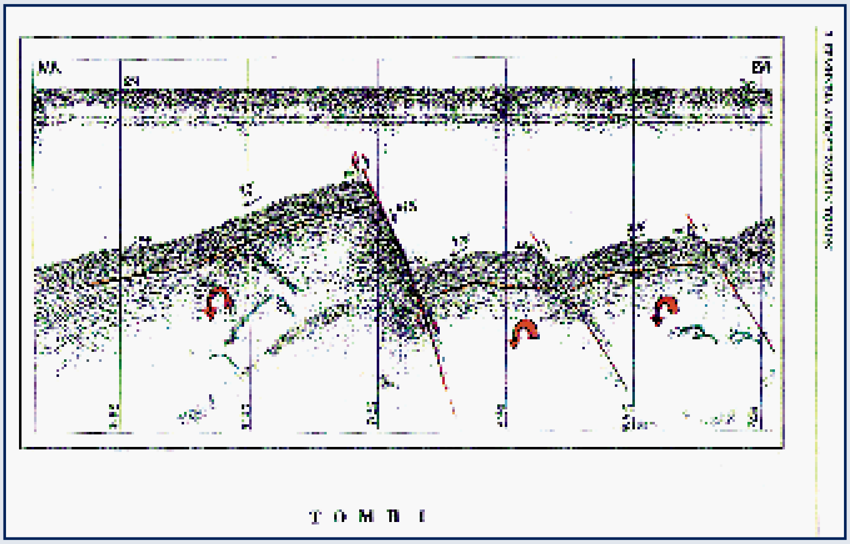


*Fig. 6.3*

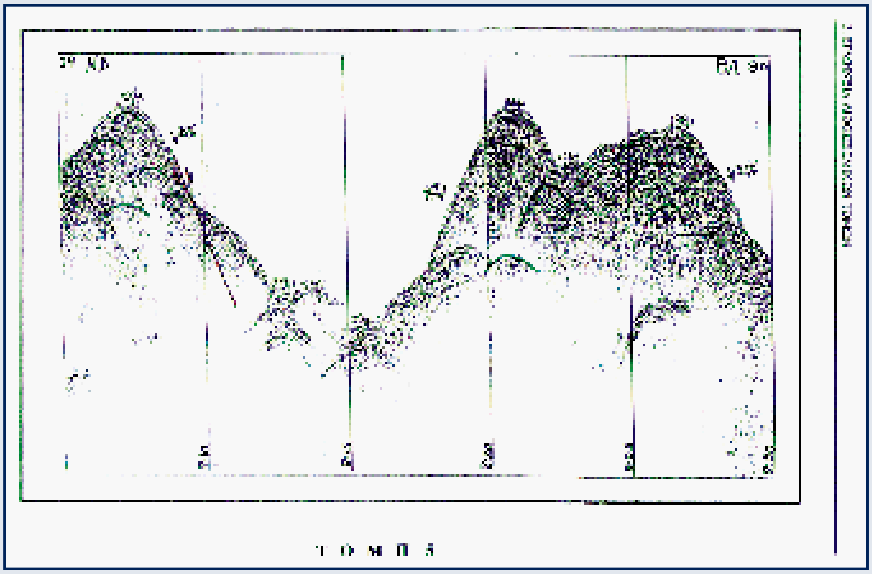


*Fig. 6.4*

II) Several outcrops of submarine volcanoes have been discovered in the area between Yali islet and Nisyros. A representative case is shown on Fig. 6.4 from the area south of Strogili islet.

III) Several small basins with sea botom depths between 250-450 m. have been distinguished among the volcanic outcrops in the area between Yali and Nisyros whereas a large basin with several hundred meters of horizontal sediments is developed between Kos and Yali with sea bottom depth at 650 m. This deep basin between Kos and Yali is characterized by thick horizontal horizons of several hundreds of meters thickness, as shown on Fig. 6.5 and Fig. 6.6, in contrast to the complex submarine topography of the highly deformed area between Yali and Nisyros.

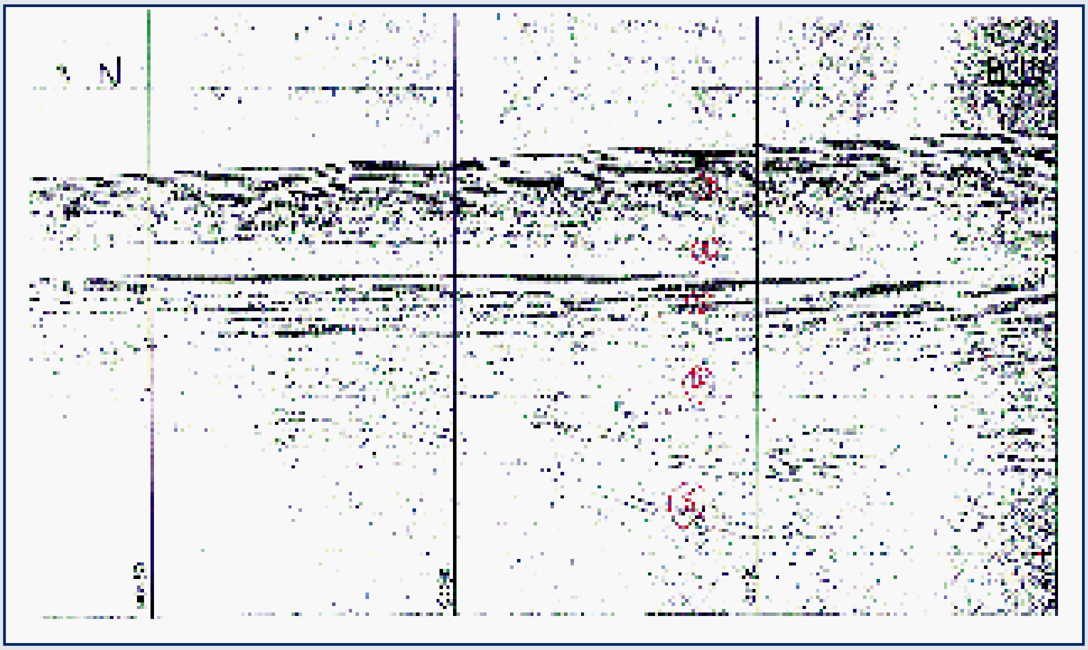


*Fig. 6.5*

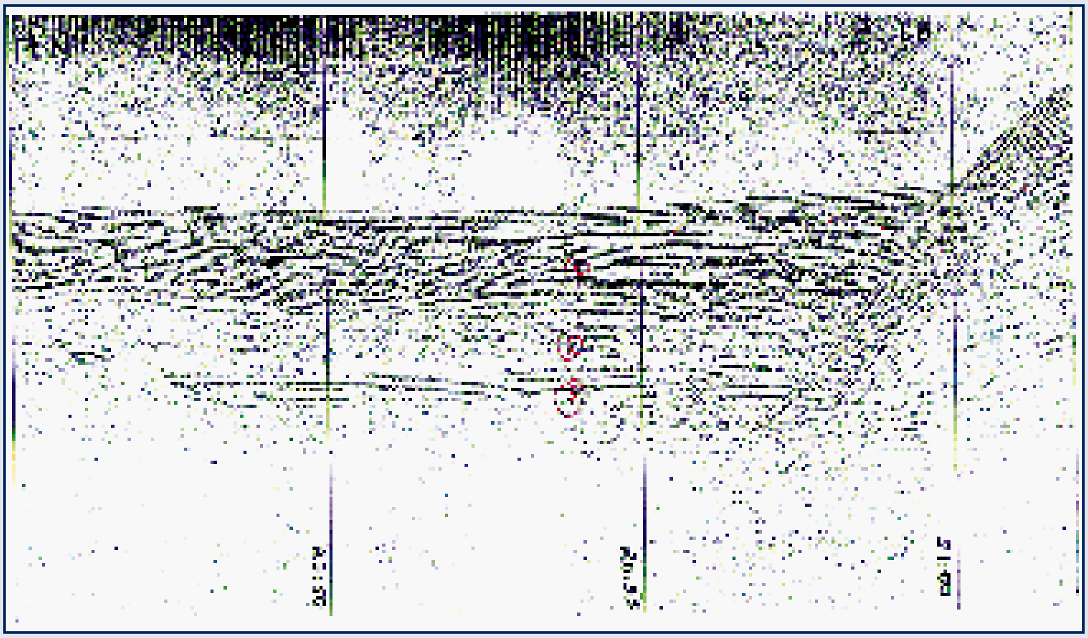


*Fig. 6.6*

## Collection of rock and sediment samples

During the cruise with the research vessel "AEGAIO" in April 1998 a preliminary sampling from the sub-marine volcanic outcrops between Yali and Nisyros was carried out, which brought to the surface some rock samples of obsidian volcanic rocks and scoriae. (Photo 6.2)

The first results of the rock analyses effected at ETH - Zurich indicate they are highly vesicular pumice bombs of surface parts of an obsidian lava flow which is very similar to that of the obsidian flow from Yali islet which erupted approximately 24.000 years ago.

Additionally, some coring has been effected in the area and several volcano-clastic horizons were observed in the very recent sediments. (Photos 6.3, 6.4)

Photo 6.2

Photo 6.3

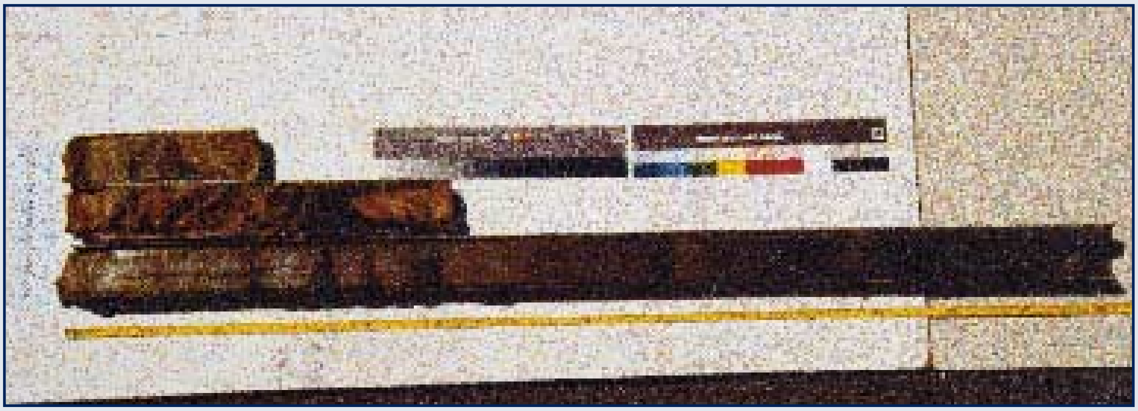


Photo 6.4

## 7. G.P.S. and Radon Measurements *(E. Lagios)*

A GPS network was established in the area of Nisyros Volcano, for the monitoring of crustal deformation during June 1997. The GPS network consists of 17 stations distributed on the islands of Nisyros and Kos. Another network of 9 stations was also established in Nisyros for the monitoring of Rn gas emission. During September 1997, both networks were remeasured. Displacements in the coordinates of the GPS stations were observed in both the horizontal and vertical directions. The horizontal displacements of the GPS stations were found to be between 13±5 mm to 37±7 mm, with direction of movement SSE for almost all of the station (Fig. 7.1). Only three stations on the NW of Nisyros showed displacements towards SSW. The vertical displacements of almost all the GPS stations showed uplift between 14±7 and 45±10 mm (Fig. 7.2).

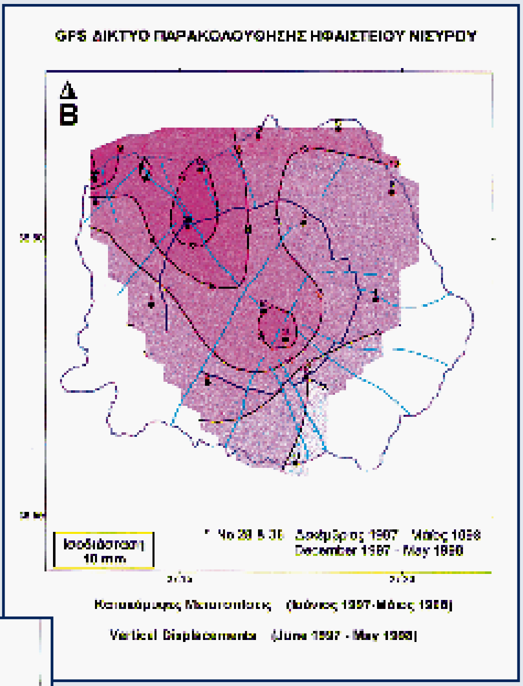



Fig. 7.2

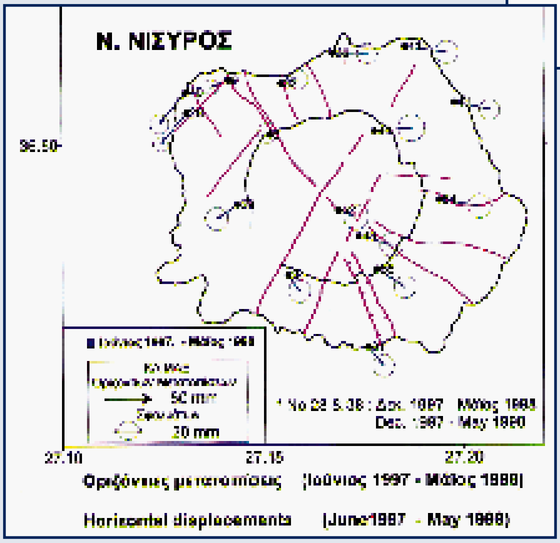



Fig. 7.1

Generally, the intense deformation osberved in Nisyros with respect to East Kos, the increased measured values of Rn gas at the northern part of Nisyros (Fig. 7.3) and the noticable seismic activity in the marine area between Kos and Nisyros, which is still in progress, constitute abnormal aspects in the evolution of the dynamics of Nisyros Volcano, requiring its immediate surveillance.

Radon emission Measurements

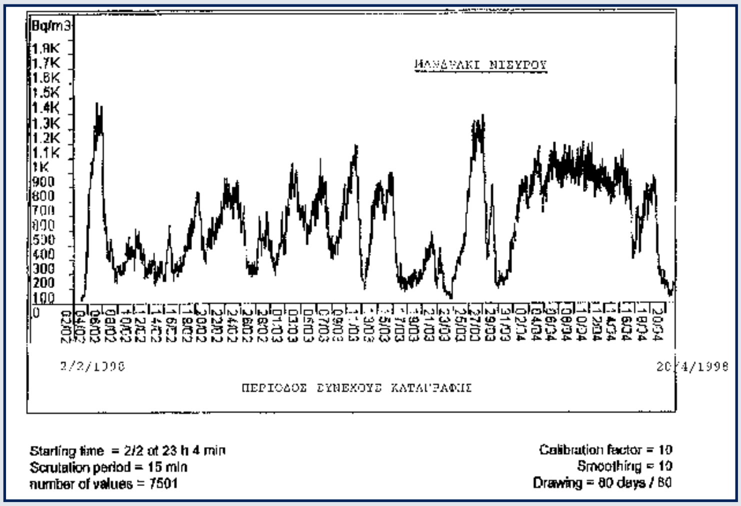



Fig. 7.3

## 8. Mantle-derived noble gases in the South Aegean volcanic arc: Indicators for incipient magmatic activity and deep crustal movements

*(V.J. Dietrich, R. Kipfer and F. Schwandner*
*Dept. of Earth Sciences, ETH Zürich, Switzerland)*

### The Active South Aegean Volcanic Island Arc

The islands of Nisyros, Yali, Kos, Santorini, Milos, Poros, Methana and Aegina constitute the South Aegean volcanic island arc, which is a result of northward-directed subduction of the African plate beneath the Aegean microplate (Fig. 8.1).

The islands of Nisyros, Santorini, Milos and Methana are considered today the most active areas in terms of a potential volcanic reactivation. Therefore, these islands were chosen for a detailed noble gas investigation.


*Fig. 8.1: The south Aegean volcanic island arc with the volcanic islands of Aegina, Methana, Milos, Santorini, Kos, Nisyros, and Yali.*

### The Volcanic Island of Nisyros

Although the last volcanic activity on Nisyros dates back at least 25000 years, the geodynamic activity, expressed by high seismic unrest, fumarolic activity and hydrothermal explosions is continuously present.

A schematic model is used to show the crustal and lithospheric structure of Nisyros volcanic island (Fig. 8.2). The upper crustal structure is based on geological and volcanological investigations of Di Paola (1974), Papanikolaou et al. (1991) and Vougioukalakis (1993) as well as on two geothermal wells (Geotermica Italiana, 1983 and 1984).

The existence of a large hydrothermal system with brine temperatures above 300°C at 1400 m depth is documented by the formation of five hydrothermal craters within the central Caldera. The most recent hydroclastic eruptions in 1873 and 1888 were accompanied by violent earthquakes, gas detonations and fire. The latter effects are due to high gas emanations of $H_2S$, $CO_2$, $H_2$ and $CH_4$ from fracture zones which cut the caldera and extend towards north north-west through the vicinity of the village of Mandraki into the island of Yali and even towards Kos. This feature indicates the existence of deep reaching zones of crustal weakness destined for magma and gas input from the upper mantle and lower crust.

Two distinct hydrothermal aquifers may be present underneath the Nisyros caldera (Fig. 8.2), according to the temperature distribution, the fluid geochemistry, the physical-chemical characteristics of the fumarolic gases and the thermal waters at the surface as well as the waters in the deep geothermal drillholes (Geotermica Italiana, 1983 and 1984; Marini et al., 1993; Chiodinit et al., 1993).

The deep hydrothermal aquifer is characterised by high temperatures above 300°C and fluids of high salinity, whereas the shallow hydrothermal aquifer shows temperatures around 100°C, high concentrations of $CH_4$, $CO_2$, $H_2$, $H_2S$ and boiling phenomena.

From June to September 1997 high-seismic activity (magnitudes of earthquakes up to 5.5 on the Richter scale) occurred on Nisyros and were accompanied by increased tectonic and fumarolic activity along the western edge of the hydrothermal crater field (Polyboted, Phlegethon).

In this respect, the scheme of events as comparable with the violent activity in 1873 and 1888 requires serious scientific examination, the establishment of geophysical and geochemical monitoring systems as well as a long term hazard, risk and preparedness assessment. Besides the permanent residents of the island of Nisyros, several hundred fo tourists enter the hydrothermal field of the Nisyros caldera daily without awareness of the entire risk situation.

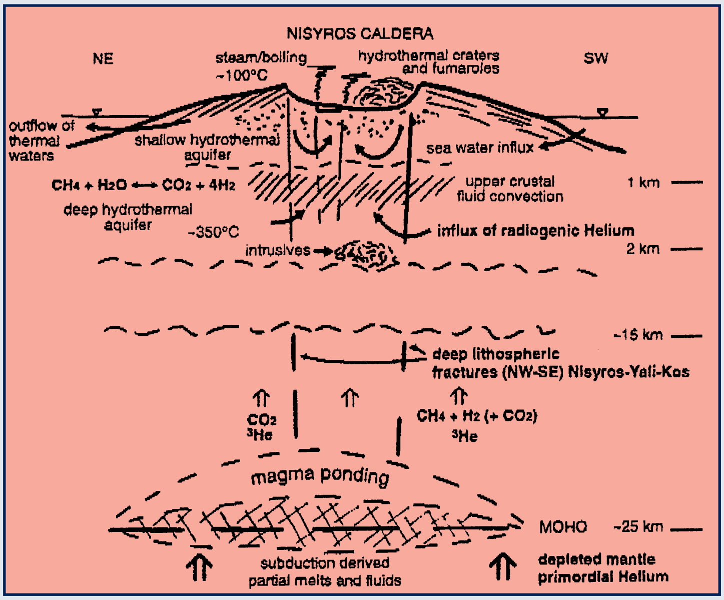



*Fig. 8.2: Schematic model of Nisyros volcanic island. Possible paths of noble gases (i.e. helium) associated with the C-H-O fluids.*

## Noble gas characteristics

Helium, as well as the other noble gases are dissolved mainly in $CO_2$-rich waters and $CO_2$ gases (Griesshaber et al., 1992) and are accompanied by $CH_4$ and $H_2$ emanations. One of the major gas reactions occurring in the crust is: $CH_4 + 2\ H_2O = CO_2 + 4\ H_2$.

Helium shows distinct isotopic signatures in the main global reservoirs; the atmorphere ($^3He/^4He \approx 1.4 \times 10^{-6}$), the Earth's crust ($^3He/^4He \approx 10^{-7} - 10^{-8}$) and the Earth's mantle ($^3He/^4He \approx (1\text{-}4) \times 10^{-5}$). Because of these differences, the analysis of helium isotopes in fluids can help to identify the origin of gas fluxes from the interior of the Earth. Thus, changes of the 3He/4He ratios during periodical measurements may indicate changes of gas fluxes due to major deep crustal tectonic, magmatic or mantle processes. The input of helium, derived from the mantle or other deep crustal sources in many volcanic areas located in convergent plate margins (e.g. Japanese Island arc) has also been found to be indicative of renewed or incipient magmatism (Sano & Wakita, 1985; Igarashi et al., 1992).

The other gases of non-atmospheric origin such as $^{20}Ne$ and $^{26}Ar$ can also be used to trace mantle or magma degassing. Often these primordial mantle components are masked by atmospheric components, and therefore, difficult to detect. This is mainly the case in lakes, thermal springs and hydrothermal waters related to volcanic activity.

The combination of noble gas ratios $^3He/^4He$, $^{20}Ne/^{22}Ne$ and $^{40}Ar/^{36}Ar$ compared to stable isotope ratios of C and O will allow an appropriate discussion on the primary origin of the noble gases, the amount of atmospheric, meteoric and hydrothermal contamination, as well as the determination of equilibrium temperatures in the hydrothermal systems. It is expected, that the noble gases are more sensitive and precise as indicators of changes of the magmatic regime (e.g. replenishment of new melts into magma reservoirs or emplacement of magmas from deep crustal levels to the suface) or changes of major tectonic processes (e.g. rapid extensional movements or crustal displacements).

## Analytical Results and Discussion

Thirteen selected water samples from Milos and Methana and fumarolic condensates from Nisyros (Table 1 and Fig. 8.3) have been analysed for their isotopic abundances and ratios of helium, neon, argon, krypton and xenon. The analyses were performed by R. Kipfer at the laboratory of Isotope Geology (Swiss Federal Institute of Technology, ETH Zürich) according to procedures described by Aeschbach-Hertig et al. (1996)

| NISYROS | Date sampling | Temp. (°C) | $^3He/^4He$ | $^4He$ (cc/g) | Ne (cc/g) | $^4He/He$ | Ar (cc/g) | Kr (cc/g) | Xe (cc/g) |
|---|---|---|---|---|---|---|---|---|---|
| Kaminakia, S-slope (cond.) | 10/14/97 | 98.5 | 5.956E-06 | 8.249E-08 | 9.530E-08 | 0.866 | 1.498E-04 | 3.132E-08 | 3.937E-09 |
| Kaminakia, N-slope (cond.) | 10/14/97 | 97.0 | 7.461E-06 | 8.976E-08 | 2.122E-08 | 4.231 | 2.755E-05 | 5.325E-09 | 6.332E-10 |
| Phlegethon, SE-fum. (cond.) | 10/14/97 | 104.0 | 7.035E-06 | 1.384E-07 | 4.280E-08 | 3.234 | 5.320E-05 | 1.030E-08 | 1.186E-09 |
| Stefanos, W-rim (cond.) | 10/14/97 | 99.7 | 7.548E-06 | 1.604E-07 | 5.038E-08 | 3.184 | 6.815E-05 | 1.319E-08 | 1.519E-09 |

| MILOS | Date sampling | Temp. (°C) | $^3He/^4He$ | $^4He$ (cc/g) | Ne (cc/g) | $^4He/He$ | Ar (cc/g) | Kr (cc/g) | Xe (cc/g) |
|---|---|---|---|---|---|---|---|---|---|
| Adamas, publ. bath (water) | 9/20/97 | 35.4 | 3.348E-06 | 1.008E-07 | 1.336E-07 | 0.755 | 1.960E-04 | 4.219E-08 | 5.448E-09 |
| Haros, well (water) | 2/20/97 | 40.3 | 1.492E-06 | 4.013E-08 | 1.398E-07 | 0.287 | 1.803E-04 | 3.565E-08 | 4.335E-09 |
| Ag. Georgios, well (water) | 9/20/97 | 44.0 | 3.362E-06 | 1.234E-07 | 1.551E-07 | 0.795 | 1.854E-04 | 3.608E-08 | 4.277E-09 |
| Paleochori beach (steam) | 9/20/97 | 103.0 | 1.467E-06 | 4.575E-08 | 1.624E-07 | 0.282 | 2.128E-04 | 4.282E-08 | 4.987E-09 |
| Kanara, therma, spring (water) | 9/20/97 | 44.5 | 4.393E-06 | 9.816E-07 | 7.769E-08 | 12.634 | 1.064E-04 | 2.243E-08 | 2.651E-09 |
| Skinopi, spring (mix+seawater) | 9/20/97 | 37.5 | 1.419E-06 | 3.347E-08 | 1.224E-07 | 0.274 | 1.855E-04 | 3.928E-08 | 5.020E-09 |

| METHANA | Date sampling | Temp. (°C) | $^3He/^4He$ | $^4He$ (cc/g) | Ne (cc/g) | $^4He/He$ | Ar (cc/g) | Kr (cc/g) | Xe (cc/g) |
|---|---|---|---|---|---|---|---|---|---|
| Ag. Nikolaos (mix + seawater) | 4/1/97 | 28.0 | 1.646E-06 | 4.658E-08 | 1.565E-07 | 0.298 | 2.369E-06 | 5.091E-08 | 6.579E-09 |
| Methana bath (water) | 4/1/97 | 31.5 | 3.181E-06 | 2.162E-07 | 7.597E-08 | 2.840 | 1.451E-04 | 3.434E-08 | 4.768E-09 |
| Methana Loutra (water) | 4/1/97 | 30.0 | 3.170E-06 | 2.020E-07 | 8.626E-08 | 2.342 | 1.588E-04 | 3.709E-08 | 5.350E-09 |

Table 1 Noble gas data from the Aegean volcanic islands: Sampling sites, features, absolute abundances and ratios. Ne, Ar, Kr, and Xe = total concentrations; cc/g = $cm^3$ of gas at standard conditions (STP) per gram of water; sampling techniques and analytical procedures in Aeschbach-Hertig et al. (1996).

The observed $^3He/^4He$ and $^4He/Ne$ ratios range from $1.419 \times 10^{-6}$ to $7.5 \times 10^{-6}$ and from 0.274 to 12.634, respectively. The Nisyros condensates fit into the array of the Japanese island arc samples which mark a mixing line between atmospheric $^3He/^4He$ ratio of $1.4 \times 10^{-6}$ and mantle derived helium with a maximum ratio of approx. $10 \times 10^{-6}$. This also applies for some waters from Milos and for the gas sample from Nea Kameni (Santorini), although, with much lower $^3He/^4He$ ratios. These latter ratios as well as those from the Methana thermal springs represent a mixing with radiogenic $^4He$ due to crustal contamination during ascent of primordial $^3He$ through the crust. The steam sample and the spring/sea water mixtures from Milos and Methana have almost the normal $^3He/^4He$ composition of air. The $^3He/^4He$ ratios reflect well the high amount of mantle derived primordial $^3He$ in the Nisyros condensates as well as in some geothermal waters from Milos. Also, in Methana, $^3He$ is detectable. These results suggest that for the island of Nisyros, mantle-derived helium may be related to degassing of magmas, probably located at great crustal depth close to the mantle/crust boundary (Fig. 8.3).

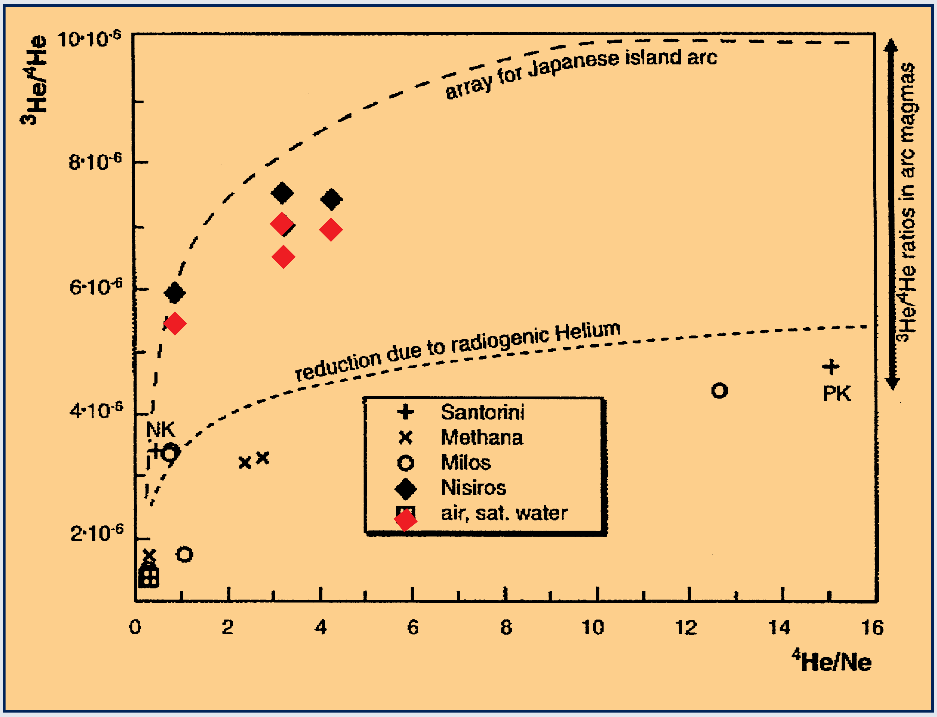



*Fig. 8.3: Correlation between 3He/4He and 4He/Ne ratios in the volcanic islands of Nisyros, Santorini, Milos and Methana. Hatched and stippled lines are mixing lines between subduction-type He (Sano & Wakita, 1985) and atmospheric He and reduction due to radiogenic He. Ne = total neon concentration. 20Ne = 0.905 x Ne. Analytical errors smaller than symbol size. Data from Santorini (Nagao et al., 1991). NK = Nea Kameni, PK = Palaia Kameni.*

The Ne and Ar isotopic ratios are close to the atmospheric values, indicating very small addition of primordial gases other that $^3He$. Kr and Xe are entirely of atmospheric origin and may be used to infer the temperature at the last equilibrium with air, for the reason that the solubility of the heavy noble gases in water strongly depends on the temperature. The Xe concentrations indicate equilibrium temperatures higher than 40°C. A detailed analysis of the noble gas abundances is in preparation.

## Conclusions and Recommendations

The high $^3He/^4He$ ratios of the Nisyros gases, sampled in October 1997 after the long period of strong earthquake activity, overlap entirely with the helium isotopic ratios measured in the high temperature fumaroles at Vulcano island (Aoelian island arc) during the magmatic/volcanic crisis in 1988 and 1989 (Tedesco et al., 1995). During this period, the temporal variations of the $^3He/^4He$ ratios, the total contents of He, $CO_2$ and $SO_2$ showed the same general trend, indicating an influx of the gases from a replenished magma reservoir at shallow depth.

For this reason, the gas emanations within the Nisyros caldera, in particular the concentrations of $CO_2$, $SO_2$, $CH_4$, $H_2$, and $H_2S$ as well as the $^3He/^4He$ ratios should be measured periodically, at least every three months. In case of reocurrance of strong earthquake activity, the fumaroles and thermal waters of Nisyros island should be monitored. The Caldera has to be closed for public, if the gas concentrations increase and isotopic ratio changes are observed; even at invariable fumarolic temperatures. There will be a potential risk for gas and hydrothermal explosions all over the caldera area, similar to the explosive events in 1873.

## Acknowledgments

We thank Th. Lyberopoulou and C. Leonis (Chemical Division, IGME) for fruitful discussions, logistic help and assistance in the field. The work was supported by the Swiss NSF, project No.2000-050494.97/1 and the Board of the Swiss Federal Institutes of Technology (BSIT).

This research is part of an interdisciplinary project on natural - vulnerability - risk assessment of Greek high-risk volcanoes and earthquake activity between the National Centre for Marine Research (D. Papanikolaou, Director), the Institute of Geophysics, Hamburg, Germany (J. Makris, Director) and the Department of Earth Sciences, Zürich, Switzerland.

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### 9. Nisyros Island: Observed damage to buildings in Mandraki *(K. Ioannidis)*

Since 1996, when the first inspection on damaged buildings took place, several groups of experts have visited the area to monitor the damage. Some macroscopic observations are presented as follows:

- Linear distribution of the damaged buildings by the foot of the rock of the Castle.

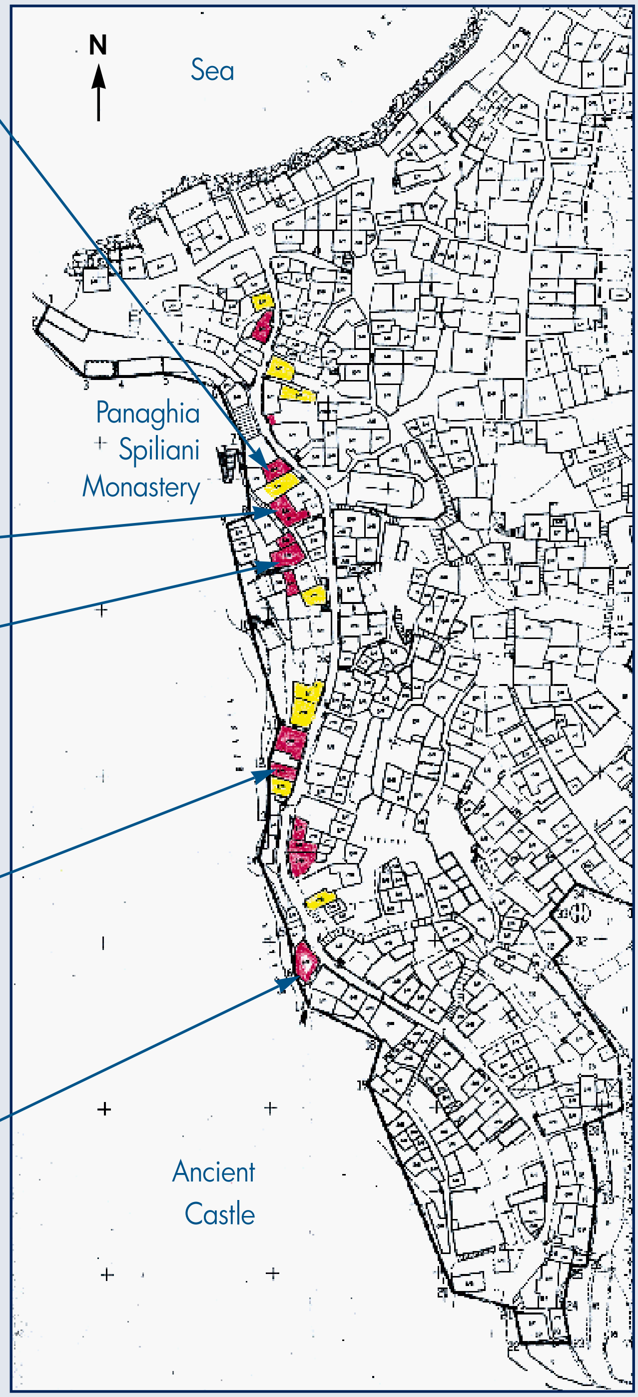
1/9/1997

25/5/1997

25/5/1997

28/8/1997

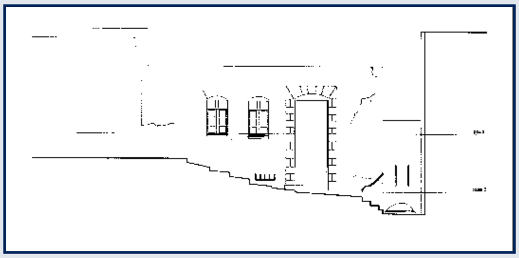
25/5/1997




Inspection: 27-8/1-9/1997

■ Building heavily damaged - dangerous ■ Building suffering medium and light damage


18/7/1996



• Damage is not of the typical earthquake induced type

• It seems that ground subsidence is a main cause of damage


18/7/1996


31/8/1998


9/10/1996


25/5/1997

• Damage progression is fast

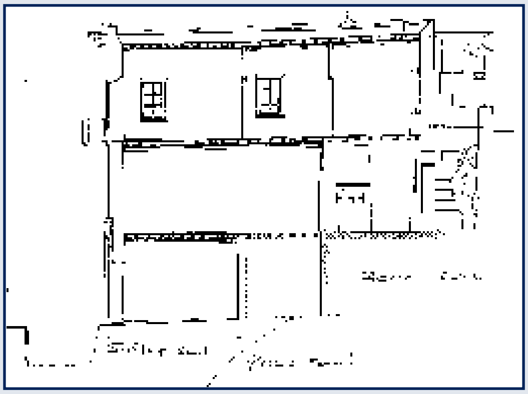

9/10/1997


26/4/1998

• Most of the damaged buildings are of a local traditional type. Several characteristics of this building type contribute to vulnerability.

Masory stucture with wick montar

Many openings in the facade



Foundation partly on bed rock and partly on softer ground

Water tanks in the building below the ground floor. Pipes from the roof to the water tank, through the masonry structure.

National Technical University of Athens conducts a research project with scientific coordinator the Ass. Prof. P. Touliatos. The project is financed by the Ministry of Aegean and aims at:

a. Defining the main characteristics (materials, connections, structure, insolation etc.) of the specific local building type.

b. Assessing the overall building performance after taking into account the damage patterns.

c. Proposing repair and strengthening methods.

Due to the peculiar type of damage and the special characteristics of the traditional building suffering damage, more scientific effort is needed before concrete conclusions regarding the causes of damage, as well as the necessary mitigation measures, are reached.

*Information and photographs by K. Hatziantoniou, Str. Eng. Consultant of Mandraki Municipality, M. Dandoulaki, Str. Eng. EPPO.*

## D3. NEOTECTONIC MAPS

1

### Neotectonic Map of Greece, scale 1:100.000
### Sheet "Lakonia - Gythio"

By: Assoc. Prof. S. Lekkas et al.

EDITED IN 1997

1. INTRODUCTION

The Earthquake Protection and Planning Organisation (EPPO) assigned the neotectonic mapping survey of "Gytheio" sheet on a 1:100,000 scale.

The studied area which lies at the south-eastern part of Peloponnessos and encompasses the Laconic Gulf, between 22.6′ N - 23.2′ E and 36.4′ - 37.0′ N.

All field work was carried out on 1:50,000 topographic maps, namely the following sheets: Gutheio, Molaoi, Reichea, Mavrovouni, Papadianika, Neapolis, Agios Nikolaos Voion and Kythira, which also includes a part of Elafonissos island.

The research team consisted of: S. Lekkas, Dr. Geologist (Assoc. Professor) - Scientific Coordinator, A. Alexopoulos Dr. Geologist (Assis Professor) and G. Danamos (Dr. Geologist), who would like to thanks EPPO for the funding of the project.

The geological structure of the study area comprises both alpine and post-alpine formations. The alpine ones belong in the following geotectonic units:

1) Eastern Greece Unit 2) Pindos Unit 3) Tripoli Unit 4) Phyllites - Quartzites Unit 4) Molaoi Unit 5) Kriti - Mani Unit.

The post-alpine formations include quaternary sediments (both marine and terrestrial), as well as neogene deposits, which are of Pilocene and Pleiostocene age. They cover a major part of the study area, mainly at the periphery of the Laconic Gulf and at the basin of Evrotas river. The latter is a post-alpine basin, bounded to the East and West by the major fault zones of Parnonas and Taygetos horsts, respectively. Other minor basins are filled with post-alpine sediments that either lie directly on the alpine basement, or are juxtaposed by faults.

From the neotectonic point of view, the study area belongs in the most seismically active regions of Greece. In whole, the earthquakes are of shallow or average depth and have had large intensities and relatively large magnitudes. Numerous cities and villages have been stricken in the past, both distant and recent (i.e. Sparti and Plytra), by severe shocks. This high seismicity pattern is a result of the fact that the areas forms part of the actual active island are of the Aegean Sea. This is also particularly stressed by the multitude of fault zones that dissect the area. The long - lasting activity of these faults is represented by the current physiographic image of the area, a main feature of which is the distinguishing of localities of high altitude that correspond to horsts, and lowlands that correspond to grabens. This geomorphological dissection has been the result of fault activity.

The contacts between the neogene and the alpine basement are usually tectonic, while there are locations where the former lie trannsgressively over the later. In the first case, i.e. juxtaposition against the basement, the neogene formations consist of deposits that fill grabens, which in turn are bounded by horsts built up by alpine formations. Such cases are the grabens or basins of Vrontamas - Vlahiotis, Elaia - Molaoi and Neapoli - Viglafia basins. In the scond case (transgressiv unconformity) the deposits are relics of the neogene formations of small thickness and extnt, occurring at places over the alpine formations.

2. NEOTECTONIC CHARACTERISTICS OF THE STUDY AREA

2.1. Trinissia - Skoutari area

This area, which is the south-western part of the neotectonic map, is characterised by the occurrence of certain relics of post-alpine sediments in grabens that are bounded by marginal faults. These faults are responsible at the southern part for the creation of coves and the topography in general. The age of the faults was not directly estimated, the fact that (i) they bound the plio-quaternary basins or cut through sediments of such age and (ii) the dynamic analysis that gives an N75E extension, which as already mentioned has created faults that juxtapose the Tyrhennian sediments, leads us to consider them active.

2.2. Skala - Vrontamas - Geraki area

This is a basin filled with neogene and quaternary deposits, separated from the basin of Sparti by the transverse ridge of Goritsa. The upper formation of the basin consists of coarse conglomerates that occur in fan form at the northern part of it. The neogene deposits of the basin either rest unconformably over the alpine rocks, or are juxtaposed against them. The detailed study of the faults that occur inside the neogene deposits revealed that they are of normal character, with a throw of a few centimeters to a metre, thus not mappable. The dynamic analysi showed an N245 extension.

To the north of Vrontamas basin, at Kosmas village, neogene deposits occur at an altitude of 1000 m. This fact denotes a tectonic activity that has continued since Upper Pliocene, as the deposits of Vrontamas basin have been dated as Late Pliocene (LALLEMANT, 1984) and occur at an altitude of 350 m. On the other hand, the coarse conglomeratic breccias that can be found at the northern part of the basin on fan form confirm this activity that must have begun before the ending of the sedimentation in the basin. The morphological terraces and the incision of streams at certain parts of the basin are due to a subsequent phase of fault tectonics, which is still considered active.

2.3. Molaoi area

The mountain mass that lies to the west of Molaoi, separates the basin of Vrontamas from the one of Molaoi - Papadianika. The latter, filled with post-alpine sediments has a general trend normal to the former, i.e. NE-SW. The mountain mass of Molaoi has rough topography and very intense incision of streams. It has to be noted that this incision also affects the talus cones that lie at the eastern and western slopes of the mountain. A multitude of faults criss-crosses the mountain, with main trends NE-SW and NW-SE.

It is, in fact a set of fault surfaces. The intense fracture tectonics has led to neogene deposits occurring now at an altitude of 750 m., east of Glykovrysi. Most of these faults have been reactivated in the recent geological past, as proven by geological and morphological criteria, which are:

a. Some of these faults have cut through the Tyrhennian beds that outcrop at the southern part of the study area, as at Elaia, at Xyli peninsula and Plytra, where the deposits occur now at various altitudes.

In certain locations they are encountered at an altitude of approximately 30 m.

b. The marginal faults south of Molaoi, trending NE-SW, juxtaposes the alpine formations against cohesive scree.

c. Faults that run parallel to the large marginal fault of Molaoi - Pakia cut through the big talus cone that develops to the east of Molaoi.

The morphological criteria are the incision of streams, the widespread development of talus cones and the successive terraces.

The marginal faults of the mountain mass of Molaoi that bound or cut through post-alpine sediments and the parallel ones to them are characterised as active, while for the remainder that occur inside the mountain mass of Molaoi there are no stratigraphical data and so we consider them as possibly active. The dynamic analysis yielded an N244 extension, similar to the one of the faults that cut through the post-alpine sediments that outcrop along the coastal zone north of Elaia are juxtaposed by a multitude of faults, some of which have cut through the Tyrhennian beds, some not.

The dynamic analysis of th faults that cut the post-alpine sediments of Molaoi shoed that they are of normal character, created by an N75 extension.

It must be remarker that, along the coastal zone to the north of Elaia, there is intense disruption of the neogene beds, as result of which has been the fact that they outcrop vertical and warped around an almost horizontal axial plane. This warping may be due to compression events that must be of local character, not affecting the greater area. There are also cetain faults horizontal slickenside striations.

Since the sediments of the area have been given a Late Pliocene age (SYMEONIDIS 1970), the compression event, if this is the case, must correspond to the Lower Pleiostocene compression event referred to for the Ionian islands (SOREL 1970).

A similar tectonic evolution holds for the area south of Xylil peninsula. This peninsula is dissected by a series of en-echelon arranged faults that give the area a particular topographic pattern. Most of these faults have a well defined exposed fault surface and created minor horsts and grabens, filled with neogene, sediments. These faults are considered active and constitute a fracture zone, as they cut through Tyrhennian deposits, which as already mentioned outcrop at various altitudes. The dynamic analysis on the faults yielded an N74 extension.

2.4. Metamorphosi - Koupia - Agios Dimitrios - Kremasti area

This area is built up exclusively of carbonate rocks of the Tripoli Unit. A particular feature of the area is that the main faults there are of NE-SW trend, contrary to the adjacent area, where both to the north-east and to the south-west the dominant fault have a general trend normal to this. Most of these faults have large exposed surfaces that disrupt the very smooth topography of the area.

Very frequently, unconsolidated colluvium is formed at the fault surfaces. Some of these NE-SW trending faults have juxtaposed the ones trending normal to them, as the large active fault the bound the graben of Reichea. We believe that these fault surfaces ante-date the grabens; however, they must have been reactivated in the Quaternary. That is they resason why two generations of striae can be found on them, the hounger of which has a strong horizontal component.

2.5. Reichea - Gerakas - Lampokambos - Kyparissi area

This area, like the previous one, is built up almost exclusively of the carbonate rocks of the Tripoli

Unit. It is characterised by large fault surfaces, many kilometers in length, trending NW-SE and forming a large graben, namely the Gerakas - Reichea - Kremasti graben. Also characteristic is the widespread development of talus cones and the reactivated fault surfaces on already formed tectonic breccias.

The most intense topography of the area is at its nort-eastern extreme, at the vicinity of the cove of Kyparissi. There, a tectonic breccia of considerable thickness (up to some tens of m.) develops parallel to the fault zones. This tectonic breccia also forms large unconsolidated talus cones.

2.6. Daimonia - Monemvassia area

There are few faults with large slickensides in this area. However, there exist certain fault surfaces, a few of which cut through some tectonic klippen and are considered inactive, as the emplacement of the tectonic nappes post-dates their last reactivation. There are no faults either, inside the neogene deposits, in contrast to the areas of Plytra, Elaia, Molaoi etc.

Intense fracture tectonics exists at the eastern side of Xyli peninsula. There is a large number of fault surfaces responsible for the creation of the small embayments of the area. The fault slickensifdes bear clear-cut striations, some of them developing on tectonic breccias. Along some of the fault surfaces certain gaps have been formed, which have subsequently been filled with calcite. In some of these cases, the calcite can be found nowadays under sea level.

Both the morphologic features and the dynamic analysis of the faults allow us to consider them inactive.

2.7. Neapoli area

Both neogene and alpine sediments outcrop at the greater area of Neapoli. The main neogene basin that develops north of the town is bounded by certain marginal faults which are considered active. There are of course other faults too, the morphologic features of which allow us to classify them as possibly active, despite the fact that they juxtapse Late Pliocene - Early Pleiostocene sediments. For the same reasons we also classify as possibly active the faults the occur on Elafonissos.

A typical feature of the area is the development of successive terraces at various altitudes. The most recent lies at 6-8 m. a.s.l., or 8-12 m. a.s.l., the previous at 30-35 or 35-40 m. a.s.l. (depending on the locations) and the oldest at 52-55 m. a.s.l. The different altitude that the terraces are found can be due to the fact that the uplift must have been more intense at the south-east, where they are at higher altitudes. These terraces develop on alpine sediments, as well as on Late Pliocene ones, which means that their age is Post-Upper Pliocene.

An active fault zone occurs at the eastern part of the Peninsula of Maleas, to the south of Monemvassia.

3. NEOTECTONIC EVOLUTION

The tectonic evolution of the study area has not been uniform throughout its extent.

Large fauls bound independent fault blocks (tectonic blocks), each of which has had its own kinematic evolution and behaviour. The large throws of the faults that create well-defined tectonic horsts and grabens of general NW-SE trend are the result not only of multiple vertical movements, but also of a certain clockwise rotation of various blocks, around a NW-SE bearing axis. The data that support this clockwise rotation are: i) the extended development of talus cones only along the south-western portion of the horsts, ii) the intense incision of streams only towards the south-west, iii) the south-westerly decrease of the thickness of the neogene sediments at the basin of Molaoi (towards the north-east the thickness of the deposits is up to 700 m.).

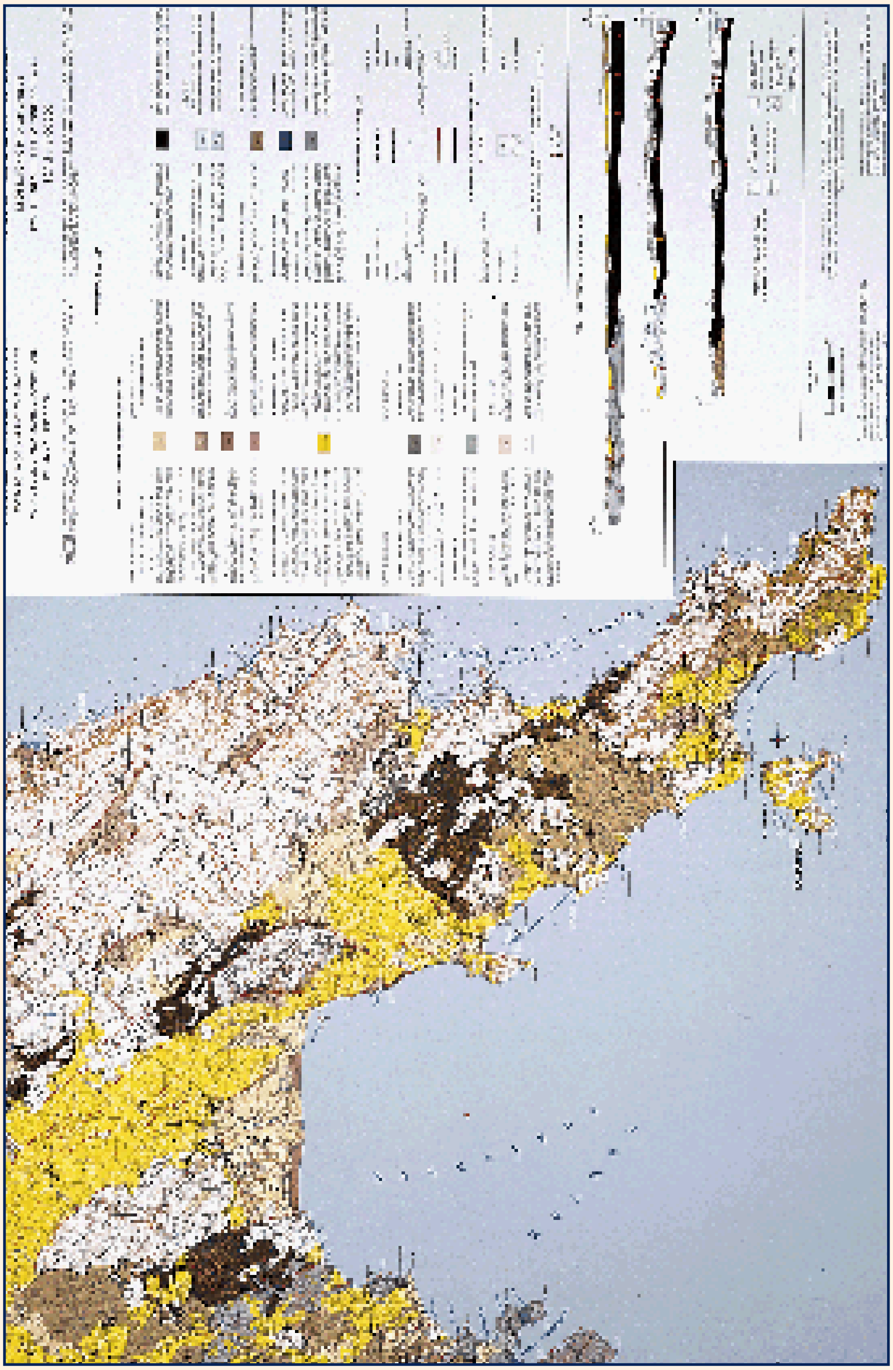
As already mentioned, the whole of the neotectonic deformation that the study area has undergone lasted throughout the neotectonic period, including Quaternary times. This deformation actually comprises an overall extension, leading to the fracturing of the alpine basement (formed by the successive emplacement of nappes) and the creation of tectonic horts and grabens. The manifestations of the fracture tectonics hold throughout the Plio-Quaternary, when there is the deposition of the post-alpine (mostly marine or laggonal) sediments in the grabens. The sedimentation is restricted inside the grabens by the marginal faults. Successive reactivations of the marginal faults led to the deepening of the grabens as they were being filled with sediments, which in turn were fractured by minor faults.

Both from literature data and from field observations we conclude that the fault tectonics is attributed to an overall ENE-WSW extension. In particular: i) The main faults of Skoutari - Lefkohoma have an NNW-SSE average trend and cut plio-quaternary desposits. They are considered active. ii) The faults of the greater Vrontamas area are due to similar extension (ENE-WSW). They are also characterised as active, since they bound grabens filled with Late Pliocene sediments. iii) The faults of the greater area of Molaoi - Elaia - Plytra have a NW-SE mean trend, while there others normal to them (NE-SW). The fact that some of these faults have been recently reactivated, together with the fact that they juxtapose Late Pleistocene sediments, allow us to consider them active. As also holds for the faults in the previous areas, they are also due to an ENE-WSW extension. iv) The faults of the greater area of Neapoli are characterised as active, since their well-documented reactivation age is Upper Pliocene - Quaternary.

Apart from the geological criteria that help in the determination of active fault surfaces, of great importance are also the observations on the morphologic characteristics of the areas. Thus, the terraces developing at the greater area of Neapoli are indicative of recent uplift. On the contrary, the submerged hamlets at Elaia - Plytra show tectonic subsidence during the recent historical times. However, this subsidence may only be attributed to eustatic movemnts.

The intense tectonic activity has been closely connected to the movements of all the tectonic blocks, throughout the whole Plio-Quaternary.

It is an indisputable fact that the historical earthquakes, as well as the recent ones relate directly to reactivations of faults, which are usually the marginal ones of the large tectonic basins in the area of the neotectonic map.



"Lakonia - Gythio Sheet"

2

## Neotectonic Map of Greece, scale 1:100.000
## Sheet "Levadia"

By: Assoc. Prof. Z. Karotsieris et al.

EDITED IN 1997

The study area lies between 22.5-23.0o longitude and 3.80-38.5o latitude. Most of this area is occupied of Alpine Formations (north of Corinth Gulf and at Perahora Penisnula). Four are the main alpine units: Olonos - Pindos Unit, Parnassos - Giona Unit, Biotia Unit and Eastern Greece Unit.

Post alpine formations essentially extend over the north coast of Peloponesse. They can be divided according to their deposition environnment into sea, lagoon or terrigeneous sediments which include alluvium and scree.Pliocene - Pleistocene sequence is the most important member of north Peloponesse and the Corinth Canal and is composed of yellow to white marls with varying content of clay minerals. It exhibits different characteristics at Kiato - Xylokastro region and at Perahora peninsula.

At Kiato - Xylokastro region there are continuous, vertical and lateral, transitions between marls and conglomerates suggesting old, buried river channels. Moreover, cross bedding suggests deltaic environment. The coastline is thought to migrate towards thw centre of the gulf (north) and therefore a progressive transition of coarse to fine deposits, of the same age, toward north is anticipated. Younger deposits should also follow thw same pattern. In fact, towards southwest marls progressively fall into sands with few conglomeratic horizons which in turn fall into conglomerates. Marls dominate at Zachoritika - Riza.

Beds dip to an average of 15-30o towards south east. Antithetic dips as much as 40o were also observed.

Eastwards there are a number of Upper Pleistocene (Strombus bubonius) or Middle Pleistocene (Patella safiana) sea terraces as high as 800 m A.S.L. Towards west there are only few signs of the older terraces left from weathering. Terraces are made of conglomerates with sandstone intercalations and some marl horizons which lie unconformably on Pliocene-Pleistocene marl and sandstone. These terraces are young (less than 500,000 years old).

At Perahora peninsula there is an occurrence of yellow-white marl, marly limestone, calcareous arenites, sandstone and conglomerate. The age of the sequence, based on gastropoda, lamellibranchs and scaphopods is Upper Pliocene to Pleistocene.

From Distomo to Steno bay a breccio-conglomerate with two representative lithofacies, can be found. It consists the Antikyra formation. The first facies involve a loose limestone breccia in a yellow, clayey matrix. The matrix varies in composition form one locality to another and fragments vary in angularity, size and amount. Occasionally there is distinct bedding, typical being the exposure on the road cuting from Distomo to Aspra Spitia, where Antikyra Formation lies unconformably on Parnassos - Giona Unit. The second facies invlolve a strongly cemented breccio-conglomerate and are on top of the first facies or unconformably on top of Parnassos - Giona limestone or flysch. Locally, Antikyra Formation comprises limestone fragments in a red clay cement. The age of the formation is not easily identified since there are no fossils (Pechoux (1964) suggests Villafranchian age and Sebrier (1977) Quaternary, based on stratigraphic relationships).

Pleiostocene screes are composed of more or less angular fragments of alpine origin and a strong cement of calcareous composition. They are karstified and usually related with tectonic events acted during Pleistocene. At places, they are covered by younger scree, generations.

Along the fault zone at the north slopes of Delfi - Arahova valley, scree is observed for several kilometers. At Delfi, it is covered by younger sediments but at Arahova is forms extenssive outcrops and can be observed on top of Parnassos - Giona flysch. Scree generation is estimated before Mindel - Riss interglacial stage which is thought to signify the uppermost karst level.

Scree, also outcrops at the following areas: Samarolakka - Hani Zemenou, Zaltsa Bay, Perahora and Ano Loutro.

Wurm and Riss glacial stages (100,000 - 80,000) years B.P.) are represented by brown, red clays and weak to moderately strong breccia. Wurm sediments in particular cover most of the study area (Sebrier, 1977). Rare Riss is interpreted (Dufaure, 1975) with continuous weathering boosted by intense tectonics.

Scree of Upper Pleistocene age occurs along major faults such as: Pissia, Ossios Patapios, Stravon, Ano Loutro, Zaltsa and Delfi.

Holocene is composed of recent alluvium, loose scree, coastal sand and Kopaida Lake deposits. At Vouliagmeni Lake (Perahora peninsula) there is a sea terrace with iron arrows which proof deposition during historic times.

There is cumulative evidence for intense seismicity during historic times at Corinth bay (Galanopoulos, 1955 & 1981). Delfi, Orhomenos, Heronia, Thiva, Itea and Galaxidi at the north of the bay, and Corinth, Xylokastro, Eliki, Sikion, Egio at the south, are only few of the built up areas affected by devastating earthquakes.

Recent seismicity is also pronounced (Corinth, 1928, 1931, 1981; Xylokastro, 1931; Ancient Corinth, 1962; Fokida, 1965; Itea, 1965) and is concentrated at the north coast. Papazachos (1986) calculated that there is a considerable possibility of a medium depth earthquake ($Ms>7.0$) until 2006 and a strong possibility of a shallow depth earthquake of $Ms>6.5$ Ground acceleration is also anticipated high (Papaioannou, 1986; Makropoulos, 1986) for Kiato - Xylokastro and Perahora penisula regions. The deformation field caused these earthquekes is tensile (Papazachos, 1976; Jackson et al., 1982; King, 1985) orientated N-S.

North of Corinth Gulf drainage is not towards the gulf, as one would expect because of the short distance, but towards north east where most depositional flat surfaces are concentrated (Kopaida region). The only worth mentioning stream north of Corinth Gulf discharges into Antikira bay. All streams of the area north of Corinth Gulf have seasonal torrential flows which, together wih uplift of the area, result to significant downcutting. Uplift, also deduced from fossil coastlines at Veresse bay, coupled with rotation towards north, gradually reduced slopes, initiated downcutting and eventually diverted waters towards closed basins. Those processes must have acted long which is supported by Antikira thick conglomeratic deposits.

Morphologic discontinuities follow alpine structures (the contact between flysch and limestone at Parnassos Mt, Distomo etc), neotectonic faults (Delfi - Arahova, Zaltsa - Sykia) orientated east and north east, or are generated due to downcutting.

At perahora peninsula there are stepped morphologic discontinuities associated with active fault zones (Pissia fault, Schinos fault, Stravon fault, Osios Patapios fault). Two depositional flat surfaces were found at 300 m and 50-80 m A.S.L. along with uplifted coastlines (wave erosion at average tide forms characteristic cavities on limestone). The phenomenon is reduced towards east (Loutraki) and at Petrites the coastline is submerged.

At Kiato important morphologic discontinuities follow the drainage pattern along major streams of north east orientation or are found along minor streams more or less perpendicular to the former. Morphologic discontinuities due to terraces resulting from ulpift of Corinth and north Peloponesse is general, were also identified. The drainage network of this region is very well developed with intense downcutting in recent alluvium at many places.

Three periods of neotectonic acitivity are identified at Corinth Gulf:

a) Pliocene to Lower Pleistocene tensile deformation, b) Compresion during lower Pleistocene, and c) Tensile deformation field from Middle Pleistocene up to today.

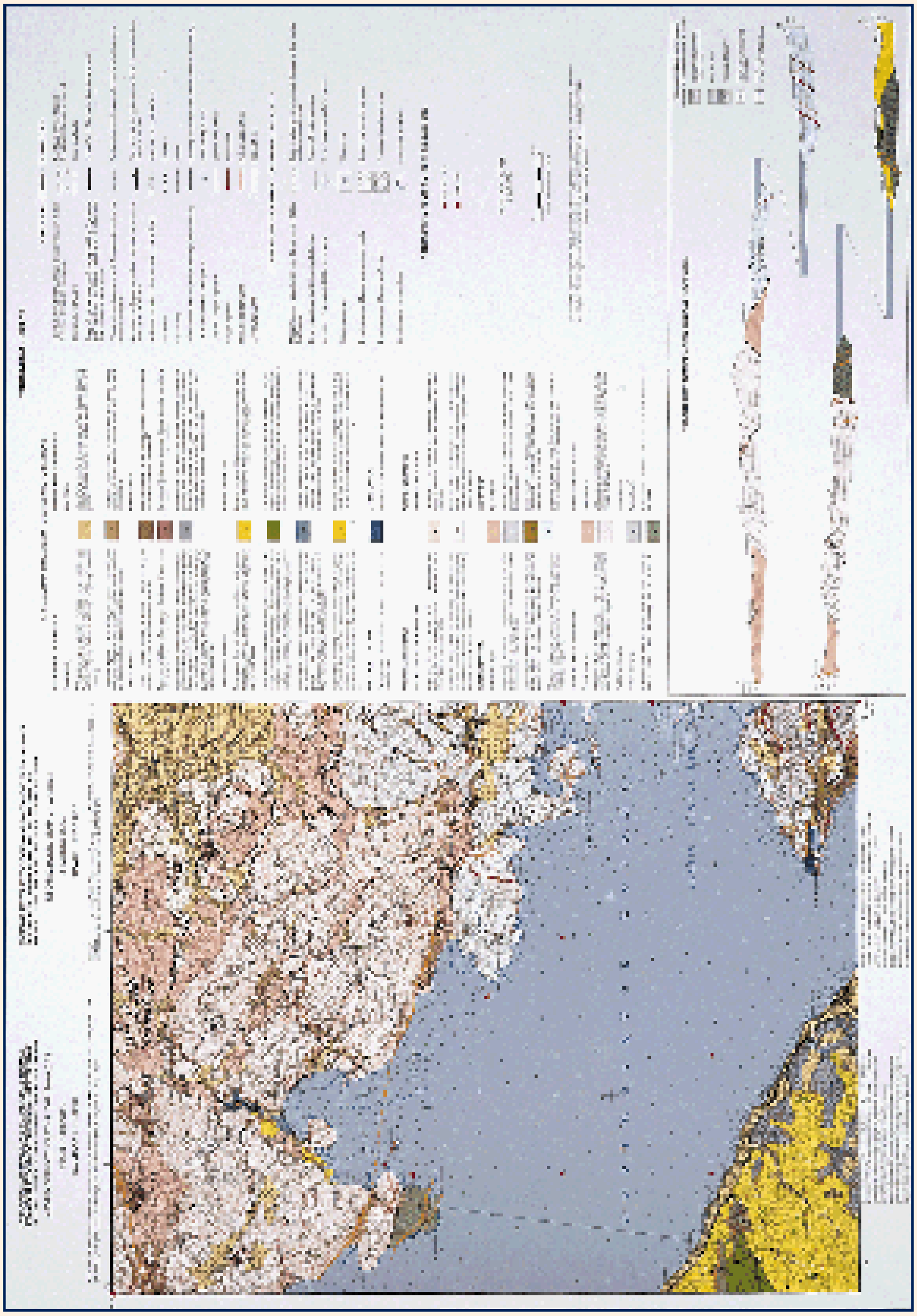
The first period is not easily recognised at the north coast of Corinth Gulf whereas the second period is readily identified by reverse faults which cross Lower Pleistocene screes and marls, and open foldss within the same marls. The third period is inferred by faults during deposition (Sebrier, 1977; Keraudren & Sorel, 1987) and is more interesting from a neotectonic point of view since it corresponds to seismic normal faults which cross sea terraces and recent screes (their age corresponds to Mindel glacial stage).

The third period is responsible for sesmic activity from Middle Pleistocene to today. North Peloponesse rotation around an east - west orientated axis, locally causes uplift which in turn gradually reduces the width of the gulf. As a concequence, faulting migrates towards north to cope with the uplift and today most active faults are underwater.

Based on faults reactivated during the earthquake of 1981 at Corinth Gulf the follow, principal stresses were found: σ1: N328oE, 78o; σ2: N109oE, 9o; and σ3: N200oE, 7o

The most importan active faults are:

a) Osios Patapios normal, sinistral fault, b) Pissia normal fault (reactivated during the earthquakes of 1981), c) Shinos fault (reactivated during the earthquakes of 1981), d) Strava fault, e) Vathia Gonia fault and f) Dombrena fault.



"Levadia Sheet"

## D4. TECHNICAL HANDBOOKS

Within the framework of the scientific activities of ECPFE is the production of a series of Technical Handbooks on technical aspects of the emergency operations after an earthquake.

1

### Technical Handbook for "Search & Rescue Operations in Earthquakes"

By: Manos Kyriazis and A. Zisiadis.

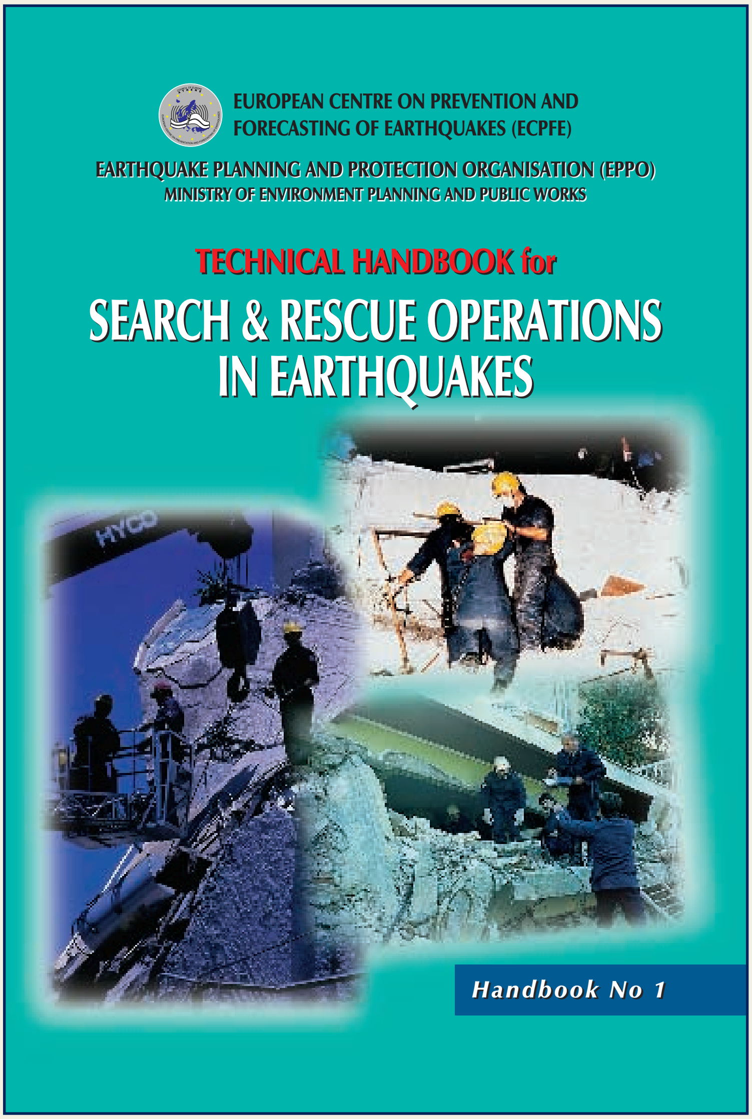
Coordinator: K. Ioannidis

The project completed in 1997.

**RESCUING PEOPLE FROM RUINS**

In spite of the progress achieved worldwide in the field of antiseismic mechanics, the possibility of building collapses and have people trapped in them is still threatening even highly developed countries. Rescue operations become a dramatic race against the clock, especially when the trapped people are injured. Therefore the rapidness with which the rescuers will reach the victims becomes the critical factor of the operation's success.

This textbook aims at providing the personnel of the rescue parties with the necessary knowledge that will increase their efficiency in the conduct of the operations. In order to successfully plan a rescue operation it is of first importance to know the mechanical behavior of the ruin. The way of approaching the victims, the personnel and the equipment used, depend on whether the building has undergone a partial or a total collapse, its materials and its volume. It is also very important to apply techniques for locating devices available. Finally penetration techniques, the necessary equipment and the security measures needed for the safety of both the victims and the personnel are being suggested.



2

## Technical Handbook for “Temporal propping, structure supporting & whithdrawal of risk elements”

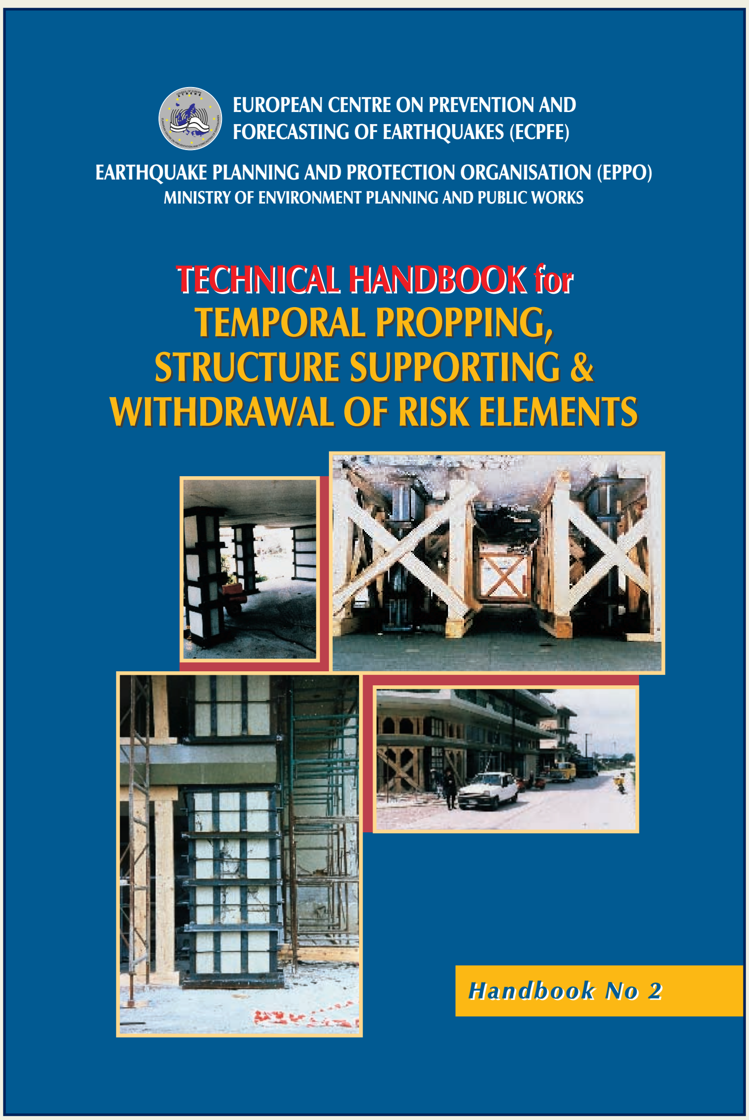
By: Ch. Frigas.

Coordinator: K. Ioannidis

The project completed in 1998.

This Technical Handbook presents the organization and methodology on “Temporal propping, structure supporting and emergency demolition”.

The methods cited in it are based on the experience gained from the Kalamata (1989), Aigio (1995), Konitsa (1996) earthquakes as well as on international experience.




This handbook aims to serve as a simple and practical tool, the construction engineers, officials of local governement and construction tradesmen such as carpenders, steel and concrete workers, etc.

In particular, the main purpose of “propping a supporting” operation is to prevent the collapse of buildings and monuments util they are repaired and strengtened for safe use.

The sections of the handbook are the following:

- Organization of the operation of “supporting a emergency demolition”, in prior and post earthquake periods, in both prefectural and municipal levels.
- Classification of the buildings to be supported.
- Criteria for prioritizing the “supporting a emergency demolition” interventions.
- Basic requirements of “supporting a propping”.
- Technical specifications of “supporting a propping”.
- List of the necessary materials, machinary and tools, as well as specialties of people involved in “supporting a propping”.
- Instructions and necessary tools for wedging e.t.c.

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