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ACTIVE FAULTING AND SEISMIC HAZARD IN ATTIKI (GREECE)

SEISFAULTGREECE

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ACTIVE FAULTING AND SEISMIC HAZARD IN ATTIKI (GREECE)

1) OBJECTIVES

Summary

The objectives of this proposal are to better understand the relationship between active faulting in Greece and related seismic hazard for the region of Athens. Special attention will be focused on relations between surface features, fault loading process, faults coupling, lithospheric processes, and wave propagation. We will adress the question of the displacement on a fault, the comparison between short time (GPS) and long time (tectonics) measurements. We will also adress the question of the "trigger" of an earthquake by a distant fault.

We will work on two different scales: 1) The study of the seismic (and tsunamis) hazard on a regional scale related to the major seismogenic zones in the Aegean. We will take into account the type of mechanisms at the source and the wave propagation (attenuation), 2) the study of the relation between the total deformation, the seismic energy release and the deep structure of a very active area which is the Gulf of Evia, the comparison and possible connection with the Gulf of Corinth.

In the Aegean sea, we will install a temporary network of 30 portable broad-band seismological stations for several month, record and locate local and regional earthquakes, compute mechanisms and infer the type of faulting. We will study the velocity structure, anisotropy and attenuation laws. We will put special attention to the intermediate depth events and their source properties, which historically caused severe damages. We also will compute tsunami hazard.

Around the Gulf of Evia we will map the active faults, measure the total deformation by satellite geodesy, study the deep structure along 2 cross sections by recording earthquakes and installing magneto-telluric instruments. Finally we will compare and combine with the observations that we have for the Gulf of Corinth to study the coupling between the two fault systems.

State of the art

Seismic hazard mitigation consists in identifying 1) the seismic sources (in time and space) and the source processes (type of motion, magnitude, rupture propagation etc...), 2) the seismic wave propagation (mostly attenuation), and 3) the local site effects on the ground motion (geometry, soil conditions, heterogeneities etc...).

As far as shallow sources are concerned, earthquake prediction, at the present time, does not seem to be an efficient method on a routine basis (Turcotte, 1991; Roeloffs, 1994). Seismic hazard mitigation is, therefore, better achieved by identifying the location of potential damaging earthquakes. But the models of source that were used to infer seismic hazard need some improvement, first because earthquakes can occur on "blind" faults, second because faults are in some way interconnected, third because some of the deformation can be creep and not related to seismic energy release (Stein et al., 1992). To study one fault independently from the neighbors is probably useless. These are the lessons that we learned recently from the Landers, the Northridge and Kobe earthquakes. Only a global approach, including geodetic measurements to know the total deformation, tectonics mapping to extrapolate in time, and seismicity can help in understanding the processes involved during a "seismic cycle". This global approach is necessary to identify the active regions, to localize and quantify the deformation. It is complementary to the statistical approach which estimates the seismic hazard from historical earthquakes catalogs which may be incomplete. Such multi-disciplinary studies have been conducted mostly in strike slip environment (in California for example). Other tectonics and faults systems could behave in a different way.

Most of the intermediate earthquakes are due to lithospheric subduction which can experience earthquakes of magnitude sometimes greater than 8. But most of these large earthquakes are in the shallow part of the subduction, where the coupling between the 2 lithospheric plates is the higher, depending also on the age of the subducted lithosphere (Kanamori, 1986). These strong intermediate events are not frequent but they affect wide zones and can cause severe damages as in Vrancea (Romania).

The ground motion during a strong earthquake depend on the local site conditions (topography, geometry, soil ...) but also on the wave propagation and therefore on the heterogeneity and attenuation that affect the seismic waves along the path (Heaton and Hartzell, 1988). These parameters are also important to estimate for seismic hazard.

Objectives

Attiki (and therefore the city of Athens) is located within the seismically active Aegean area between two deforming extensional features which are the Gulf of Corinth and the Gulf of Evia. We want to study the seismic hazard at 2 different scales.

1) At a regional scale (the Aegean) we want to study the effects of seismic sources located within the Aegean, both shallow and of intermediate depth, the inferred risk of tsunami, the characteristics of the ground motion related to the crustal and upper mantle structure.

2) At a local scale we want to study the mechanism related to the tectonics of the Gulf of Evia, measure the displacement on different faults, compare with the results that we have for the Gulf of Corinth, look for possible interconnection between the 2 structures.

These scales are complementary and both are important for seismic hazard mitigation in Attiki. At this 2 scales we will focus on different tasks that together will give us a better understanding on the tectonical mechanisms, continental tectonics and geodynamics, inferred seismic sources and ground motion.

We will install a network of 30 digital broad band seismological stations within the Aegean sea. We will record, locate and compute mechanism for both shallow and intermediate depth earthquakes. We will study the velocity, heterogeneity and attenuation structures to infer the ground motion during a strong earthquake. We will precise the type of faulting on which tsunami depend and compute tsunami hazard.

Around the Gulf of Evia we will conduct a similar study as we did previously around the Gulf of Corinth. We will map in detail the active faults, quantify and date the motion on the faults. We will measure the deformation with satellite geodesy. We will compare the two active shallow features. We will study the crustal and upper mantle structure beneath both grabens and look for possible deep rooted structures with seismology and magneto-tellurics. We will look for possible interconnection between faults to infer any seismic coupling between them.

These studies will precise the cause of seismic hazard in Central Greece and mostly around Athens, but also will help in defining methodologies of seismic hazard mitigation in continental tectonic domain. In most of the European countries the deformation is small, the loading process is slow, and the seismicity is moderate. This means that destructive earthquakes of magnitude greater than 6.0 are rare and the return period could be long (several thousands years). But in most of the European countries there are historical evidences of damaging earthquakes of magnitude above 6.0. And because of the increasing industrialization of the European countries, these earthquakes could cause heavy damages. The Aegean area is a region of important deformation and high seismicity, it offers an unique opportunity to study seismic hazard in continental domain. Our proposal is important for seismic hazard mitigation around Athens, but also will help for the evaluation of seismic hazard in other European countries. Such detailed studies are necessary before studies on earthquakes prediction because they help in defining possible test sites.

2) WORK CONTENT

Task 1, the regional scale

The actual seismological network is not very dense and mostly equipped with 1-D seismometers, which does not allow to precisely locate earthquakes, compute focal mechanisms and work on wave propagation and the related structure. For the last 10 years, we have been installing temporary seismological networks at a local scale to study seismotectonics. The instruments were mostly vertical seismometers connected to "smoked paper" recorders and the information that we gathered was useful to locate earthquakes and compute mechanisms in region where we could deploy homogenous networks, and therefore restricted to continental Greece.

Mostly because of technical limitations (portable digital seismological stations are recent and available in reasonable number only recently), we restricted our studies to seismotectonics and could not consider working on the seismological signal itself. Now that techniques improved considerably with "digital seismology" and especially with portable digital recorders and mobile broad-band seismometers, we can work on the seismic signal and the information that is carried in the seismogram itself (late arrivals, amplitude and frequency range). We can install dense temporary broad-band digital seismometers and study seismic source properties, crsutal and upper-mantle strcuture.

We want to install a network of 30 broad-band seismometers over the Aegean during a 6-month period of time (Fig 1). Most of them are available trough the French Lithoscope program, a little part of them will be acquired during the project. The data loggers are DAT continuous recorders with an autonomy greater than 6 weeks, the power consumption is small enough that we can use a car battery for several weeks, and the time is calibrated by an external GPS or radio receiver. The seismometer are either Guralp CMG40 (20 sec of natural period) or CMG3 (100 sec of natural period) which are now available in France or in Great Britain. We will locate earthquakes, study the source properties of the earthquakes, compute attenuation laws and regionalize, study the velocity structure of the crust and upper mantle by the receiver function technique and surface waves technique, study the anisotropy of the upper mantle by S-wave splitting. We have a good experience on temporary seismological network, about instrumentation, and about the Aegean, so we have no worries about technical and logistical problems.

partners:

D. Hatzfeld (UJF) will be responsible of the installation of the seismological network. H. Lyon-Caen (IPGP), K. Makropoulos (NKUA.SL), A. Kiratzi (AUTH), P. Hatzidimitriou (AUTH), C. Papazachos (AUTH), D. Panagiotopoulos (AUTH) and K. Priestley (UCAMB) will help also for the installation, but also for the maintenance of the stations that we plan to visit every month for calibration and check. The installation of the network takes about 10 man-month, the maintenance of the network during 6 month will take about 24 man-month.

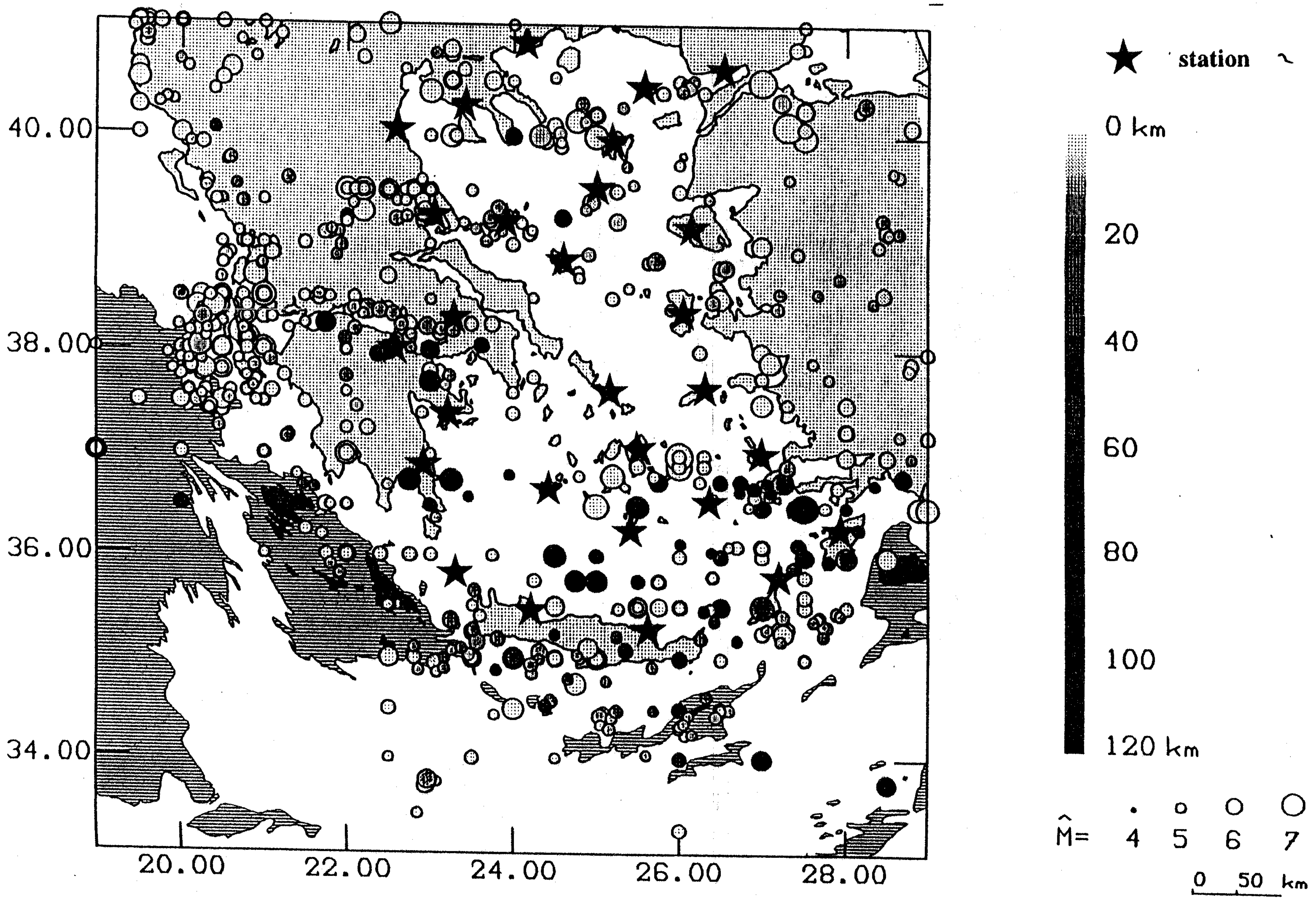
1-1 Shallow tectonics

The Aegean region is located between two major lithospheric plates (Africa and Europe) that are converging at a rate of about 1 cm/year but the motion across the Hellenic trench, where a lithospheric subduction takes place, is of about 4-5 cm/year. The difference between the two rates is likely to be due to several causes: 1) the westward motion of Turkey along the north Anatolian fault and 2) the internal deformation within the Aegean.

The Aegean region is certainly a region of complex tectonics. We observe shortening perpendicular to the Hellenic arc in the external part, and extension, trending mostly N-S, within the internal part and especially in the Aegean sea (McKenzie, 1978). The morphology and seismicity are different between the north Aegean sea and the south Aegean sea and most of the

Fig 1

ISC seismicity map (mb>5.0) and location of the broad-band seismological stations that we plan to install.



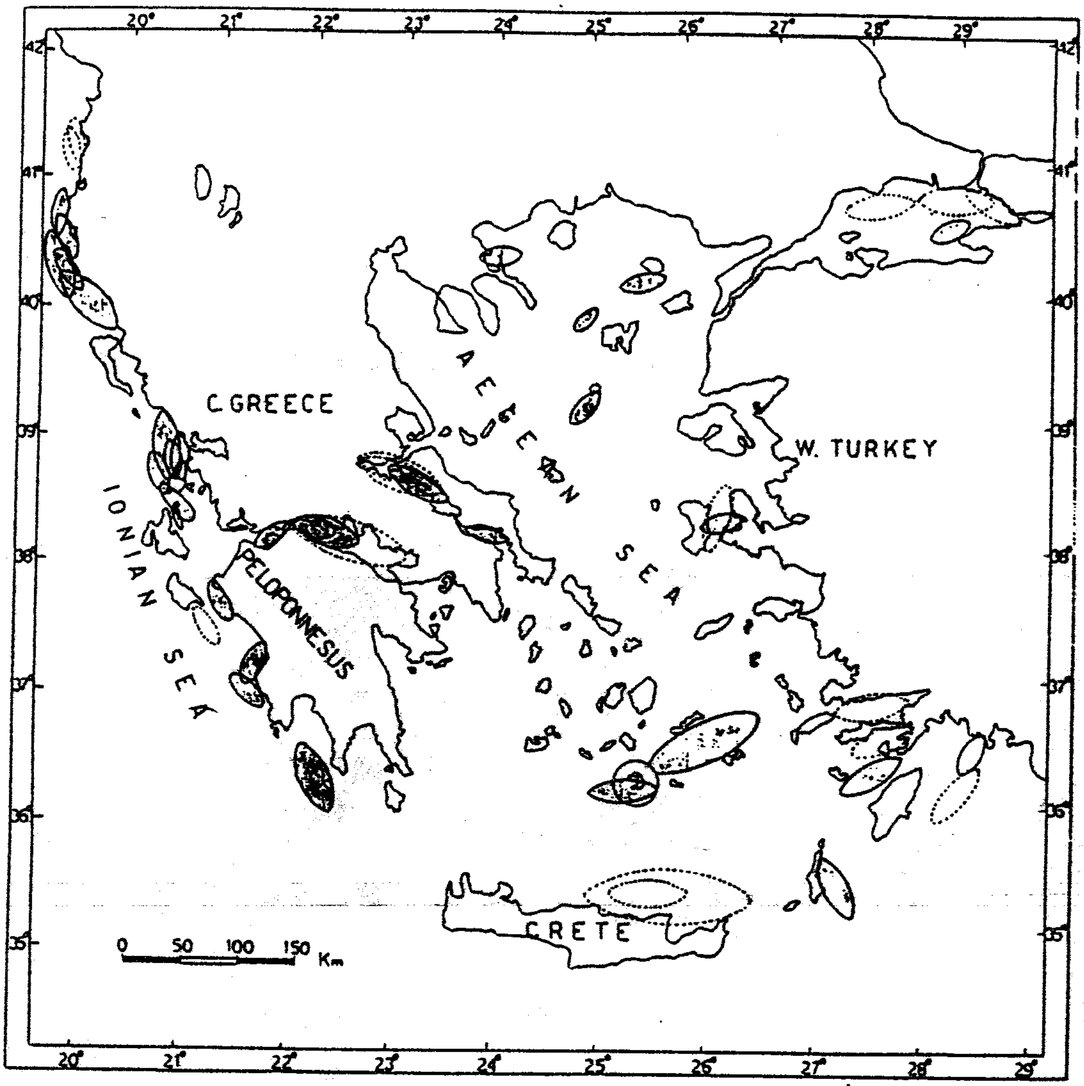


Fig 2

Geographical distribution of tsunamis around Greece (Papazachos et al., 1986) region is under sea level where it is difficult to map active faults, even using marine geophysics (Mascle and Martin, 1990). The most dramatic feature is the North Aegean Trough which is a serie of deep fault-bounded basins located in the continuation of the North Anatolian fault. Seismic activity represents as much as 50% of the total deformation (Jackson and McKenzie, 1988), large earthquakes occur frequently and during the last 50 years two earthquakes were of magnitude larger than 7 and about a dozen of magnitude larger than 6. The focal mechanisms are mainly strike slip motion (Taymaz et al., 1991).

On the opposite, the South Aegean sea is a region of subsiding basins of Miocene age, cut by numerous normal faults. These basins are the surface expression of intense stretching with a factor of 2, and therefore a thinning of 2 either. The seismicity is lower, which means that strong earthquakes do not occur frequently and it is difficult to infer any pattern for from teleseismically computed focal mechanisms. The strongest earthquake of this century (Ms=7.2), however, occurred near Amorgos in 1956 (Papadopoulos and Pavlides, 1992).

We will locate the earthquakes and compute mechanisms using classical methods that we practice for a long time now. We will also use more sophisticated techniques as S-wave polarization which were successful in Corinth or in Crete.

partners:
D. Hatzfeld (UJF), A. Kiratzi (AUTH), K. Makropoulos (NKUA.SL) will take in charge the processing of the data. Reading of the data, location and computation of focal mechanisms will need about 12 man month.

1-2 Tsunamis

The Amorgos earthquake was widely felt in the Cyclades islands, but more dramatically provoked a tsunami which reached an elevation of 50 m in the island of Patmos (Papazachos et al., 1985). Tsunamis (Fig 2) are part of the seismic hazard for the Aegean sea and the Gulf of Corinth (Papazachos et al., 1986). Because most of the seismic faults are normal faults, they can be responsible of important tsunamis, which can cause severe damages. Therefore a study of the seismically active faults, their motion together with the bathymetry is necessary to perform tsunami modeling. We will investigate further historical tsunamis (Papazachos et al., 1986). We also will infer from seismotectonics information, the potentially tsunamigenic faults in the Aegean. We will use bathymetric information to model and compute tsunami hazard in the Aegean, and also in the Gulf of Corinth which experienced damaging tsunamis in the past.

partners:
B. Papazachos (AUTH) will be in charge of historical tsunamis. We will collaborate with R. Gaulon and P. Bernard (IPGP) for the modeling. The work on tsunami will take about 6 man-month.

1-3 Structure

The amplitude of the ground motion observed during an earthquake is partially due to heterogeneities along the path (as the variations in crustal thickness and the attenuation of the seismic waves). In the Aegean the velocity structure is not precisely known (Makris and Strobbe, 1984) and the crustal thickness varies from 20 km beneath the southern Aegean sea, to 40 km beneath continental Greece. The upper mantle structure is also heterogeneous (Fig 3) (Panagiotopoulos and Papazachos, 1985; Spakman et al., 1993; Hearn and Ni, 1994, Papazachos et al, 1994), and it is also likely that attenuation (Fig 4) is non homogenous (Hashida et al., 1988).

We want to study the velocity structure of the crust and upper mantle inverting travel time residuals of local and teleseismic earthquakes. Having a dense network, above the region that we want to study, will greatly improve the results that were computed by Spakman et al.(1993) using Aegean earthquakes recorded in distant stations.

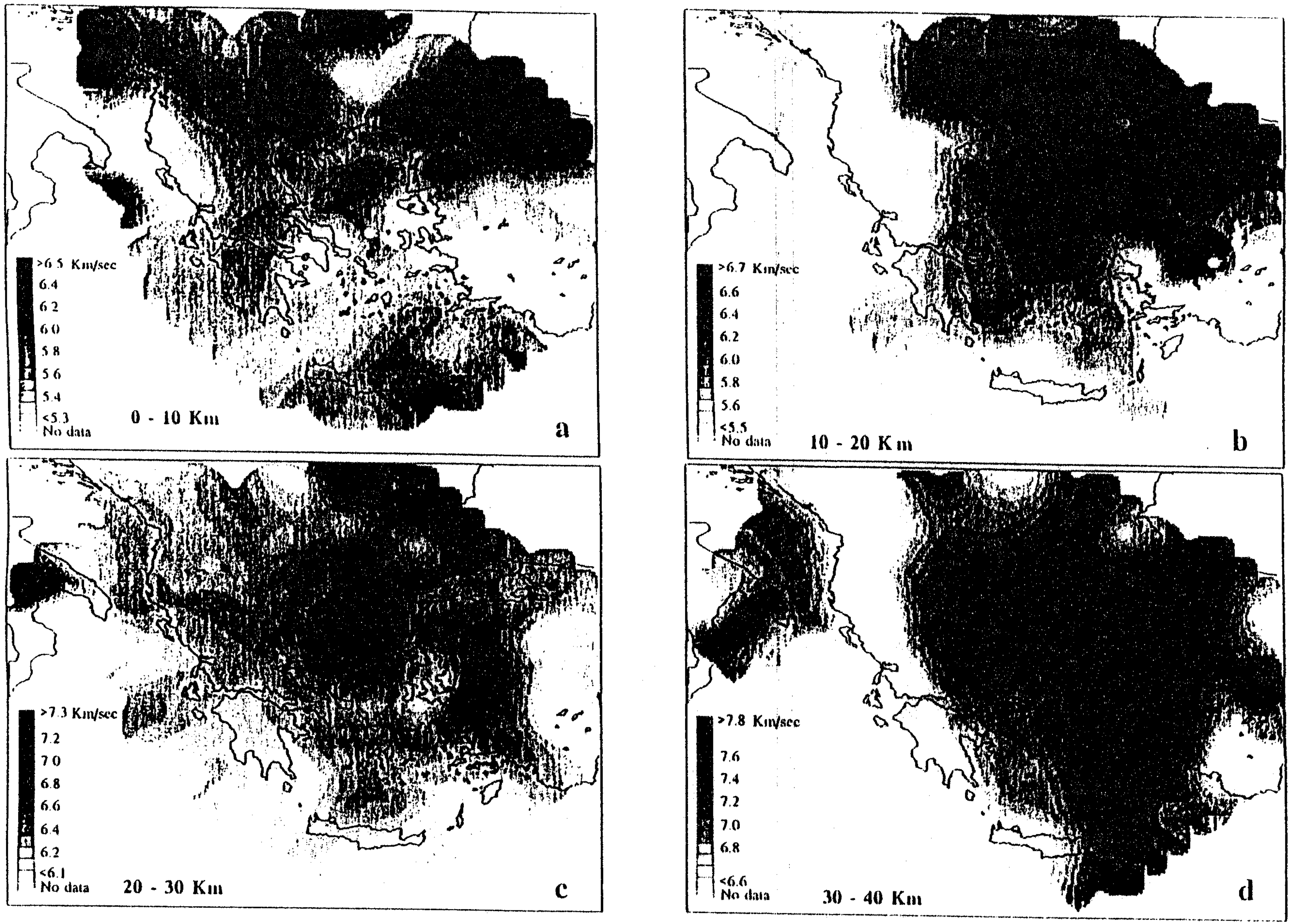


Fig 3 **Tomographic images of the crust and upper mantle (Papazachos et al., 1994)**

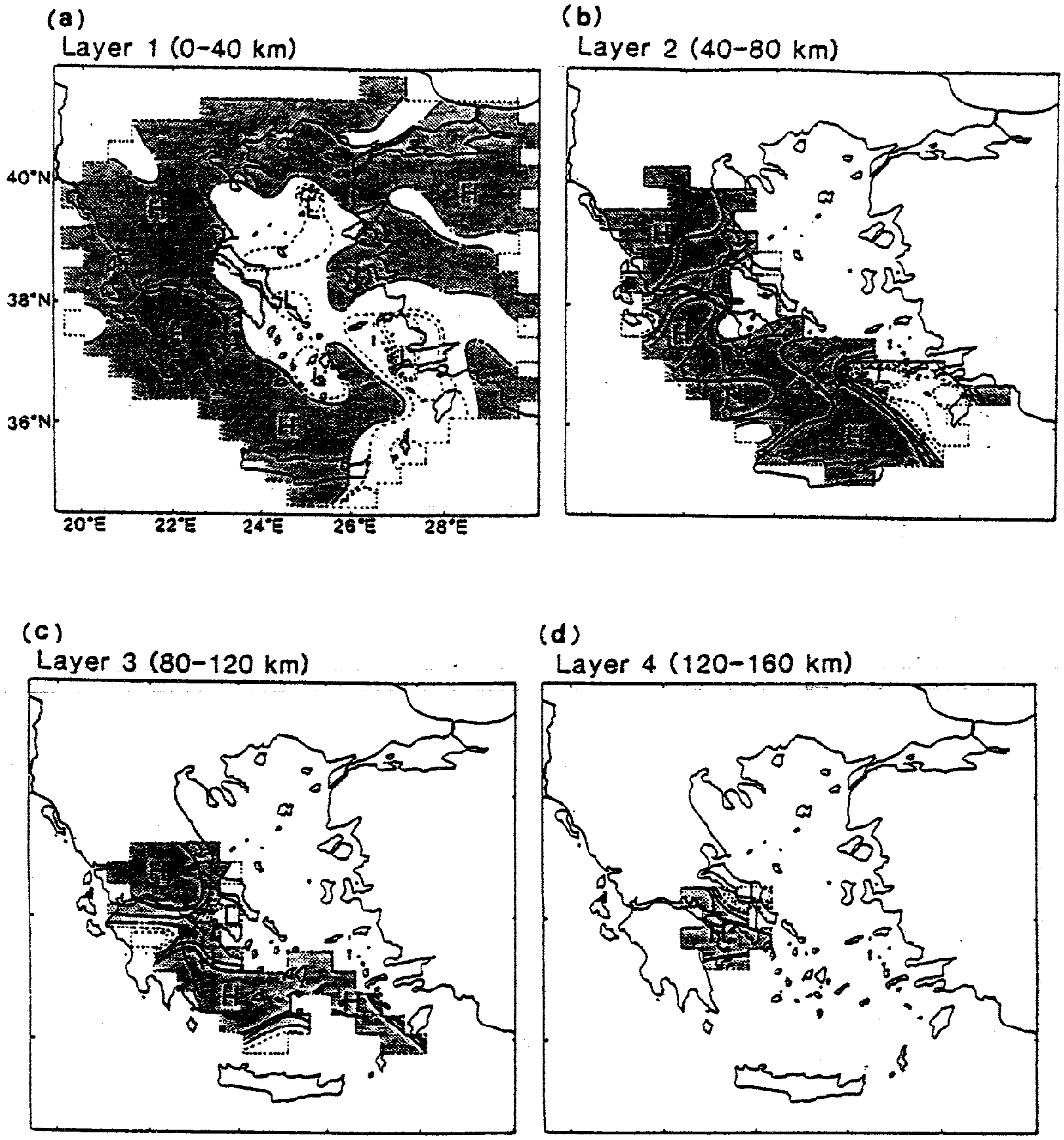


Fig4 **The attenuation structure determined by the inversion of felt intensities for local earthquakes in Greece (Hashida et al., 1988)**

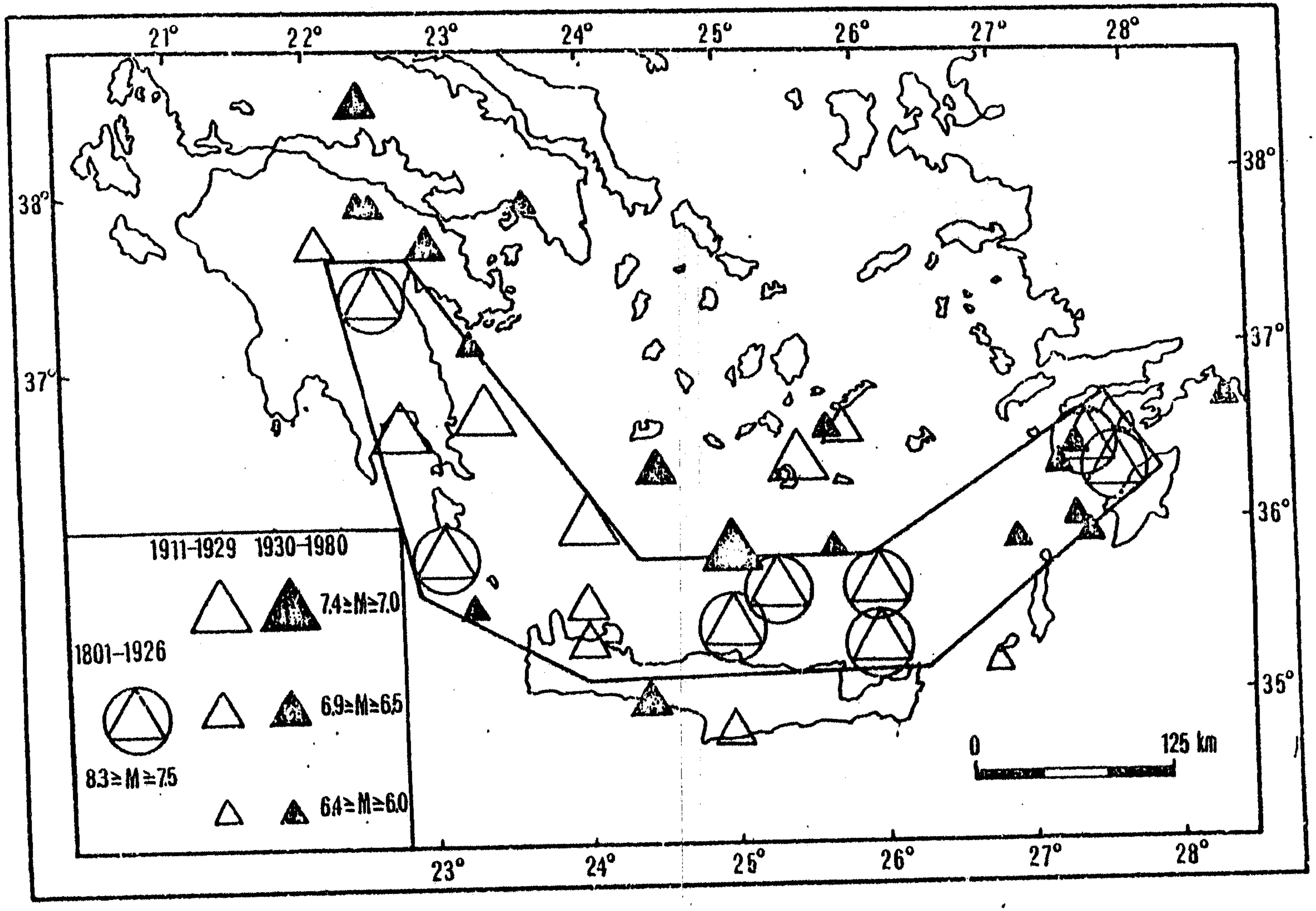


Fig 5 Map of strong (Ms>6.0) intermediate depth earthquakes (Papazachos, 1985)

We will also use receiver function technique, that was successful in Turkey, to get a good estimate of the velocity structure for the crust and upper mantle and we expect to record about 10, strong enough, teleseismic earthquakes per month.

Because of the large band-pass of the seismometers we will record surface waves that we will use both for the study of crustal and upper mantle velocity structure. This information that is totally independent from the body waves will, therefore, constrain seriously the results obtained by the receiver function technique. Because of the lack of long period seismometers in the Aegean, this will be the first serious attempt to study the Aegean by surface waves.

One more sub-task that we will investigate is anisotropy in the upper mantle and the relation with shallow tectonics. Anisotropy is related to the flow in the upper mantle, to geodynamics and as a consequence to shallow tectonics. The relation between surface features (as volcanoes) and mantle structure is important. Relation between upper mantle anisotropy (and possibly flow) and shallow tectonics will put constraints on the coupling or decoupling between the crust and upper mantle deformation.

We will obviously work on attenuation and try to regionalize in the Aegean. This parameter of the seismic wave propagation varies on a broad range and is necessary to quantify for an estimate of the ground motion during an earthquake. We will work on coda-Q, and intrinsic attenuation.

partners:
All the seismological partners will be involved at some moment in this study on the structure of the Aegean and related ground motion and **D. Hatzfeld** is the coordinator of the scientific interpretation. Most of us have been involved previously in the necessary techniques. D. Hatzfeld (UJF) in 3d-inversion and surface waves, K.Makropoulos (NKUA.SL) and P. Hatzidimitriou (AUTH) in attenuation, K. Priestley (UCAMB) in receiver function and anisotropy, H. Lyon-Caen (IPGP) in surface waves. The man-power necessary to achieve the task is difficult to estimate because of the great variety of techniques that will be used. We are confident in the quality and originality of the data that will be gathered. These data will provide strong constraints on the model that are presently available for the Aegean. We suppose that a amount of 36 man-month is necessary to achieve the task.

1-4 Subduction

Because of the active subduction zone that takes place beneath the south Aegean sea, part of the seismicity is of intermediate depth. This subduction zone is not geometrically well defined, and is likely to dip shallowly beneath the Peloponnese and steeply beneath the Dodecanese islands (Hatzfeld et al., 1989). Earthquakes of magnitude greater than 5 occur regularly beneath southern Peloponnese or beneath Crete at 100 km depth but there is no evidence of instrumental strong destructive earthquakes of intermediate depth in the Aegean and only historical catalogues refer to earthquakes of intermediate depth of magnitude greater than 7 (Fig 5). One of this strong event occurred south of Crete in 365 BC and is likely to be of magnitude greater than 8, but it could be related to the shallow part of the subducted slab (Papazachos et Papazachou, 1989). We need information about the geometry of the slab, about intermediate earthquake source process, about attenuation along the path of the seismic waves. We need to estimate the maximum possible magnitude both in the inner part of the slab, in the outer part of the slab (along the trench) and within the slab. And we know that earthquakes of strong magnitude occurred in all these 3 places but we have no idea yet of the maximum magnitude that we can expect.

partners:
A. **Kiratzi** and B. Karakostas (AUTH), D. Hatzfeld (UJF), and K. Makropoulos (NKUA.SL) will be involved in this study which will take about 12 man-month.

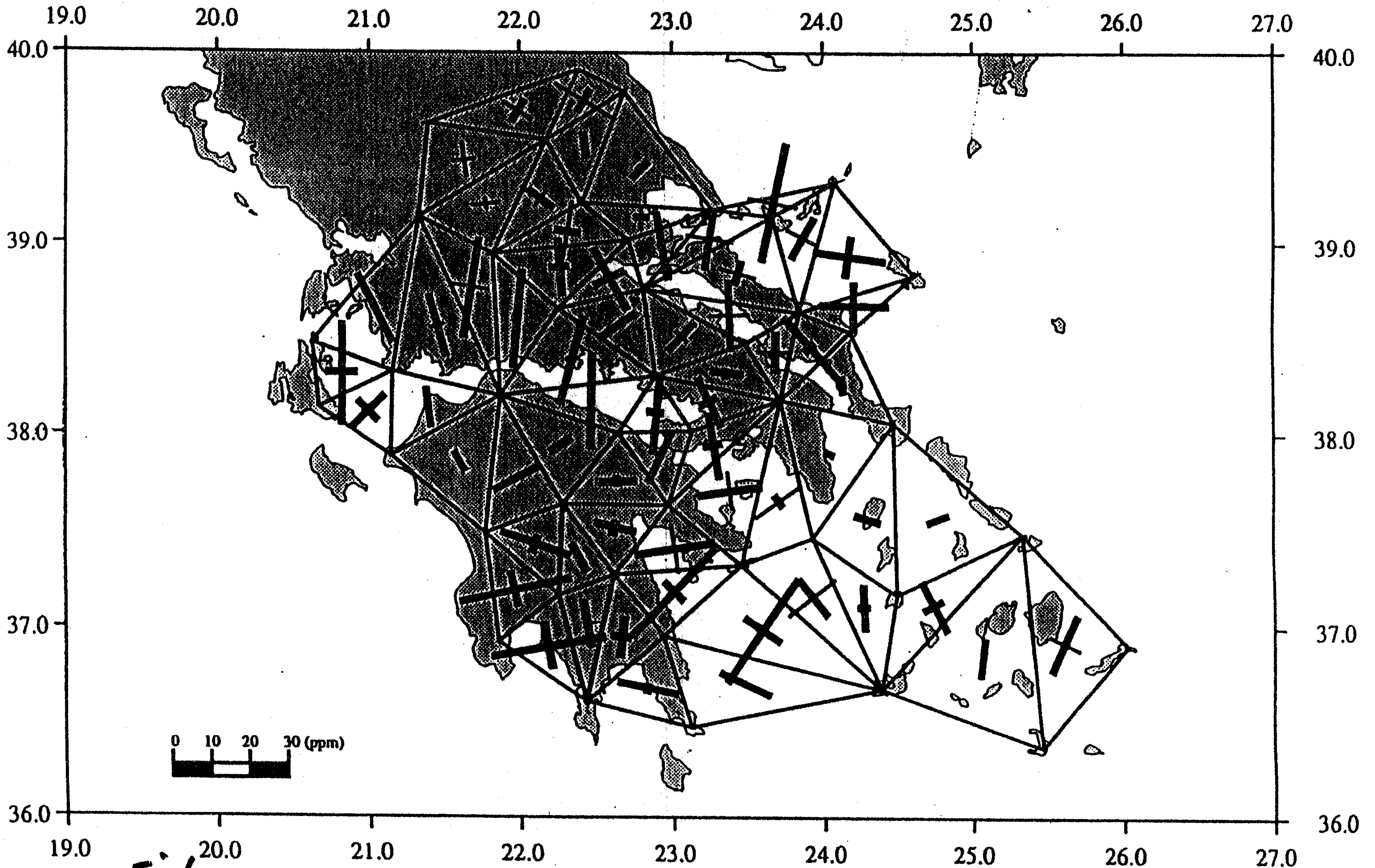
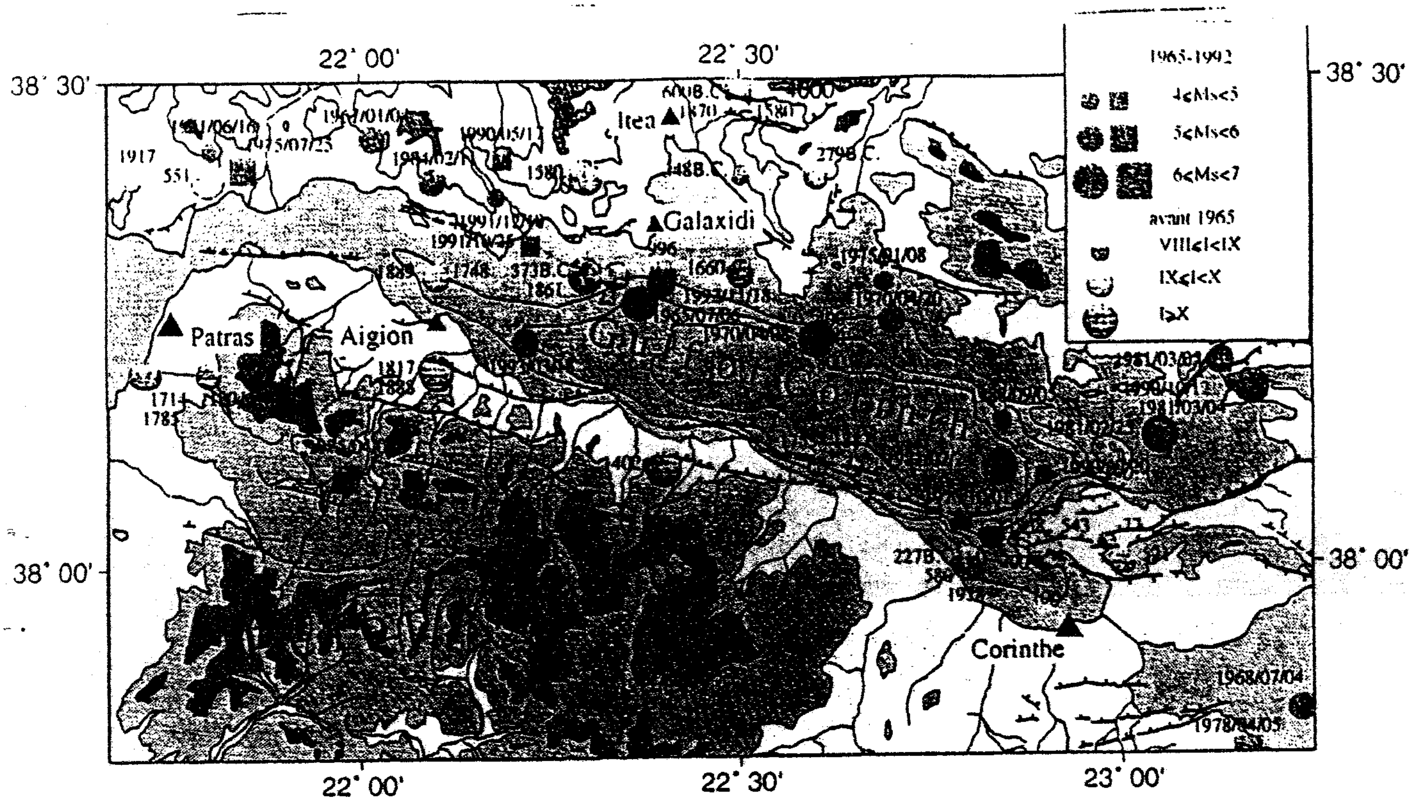
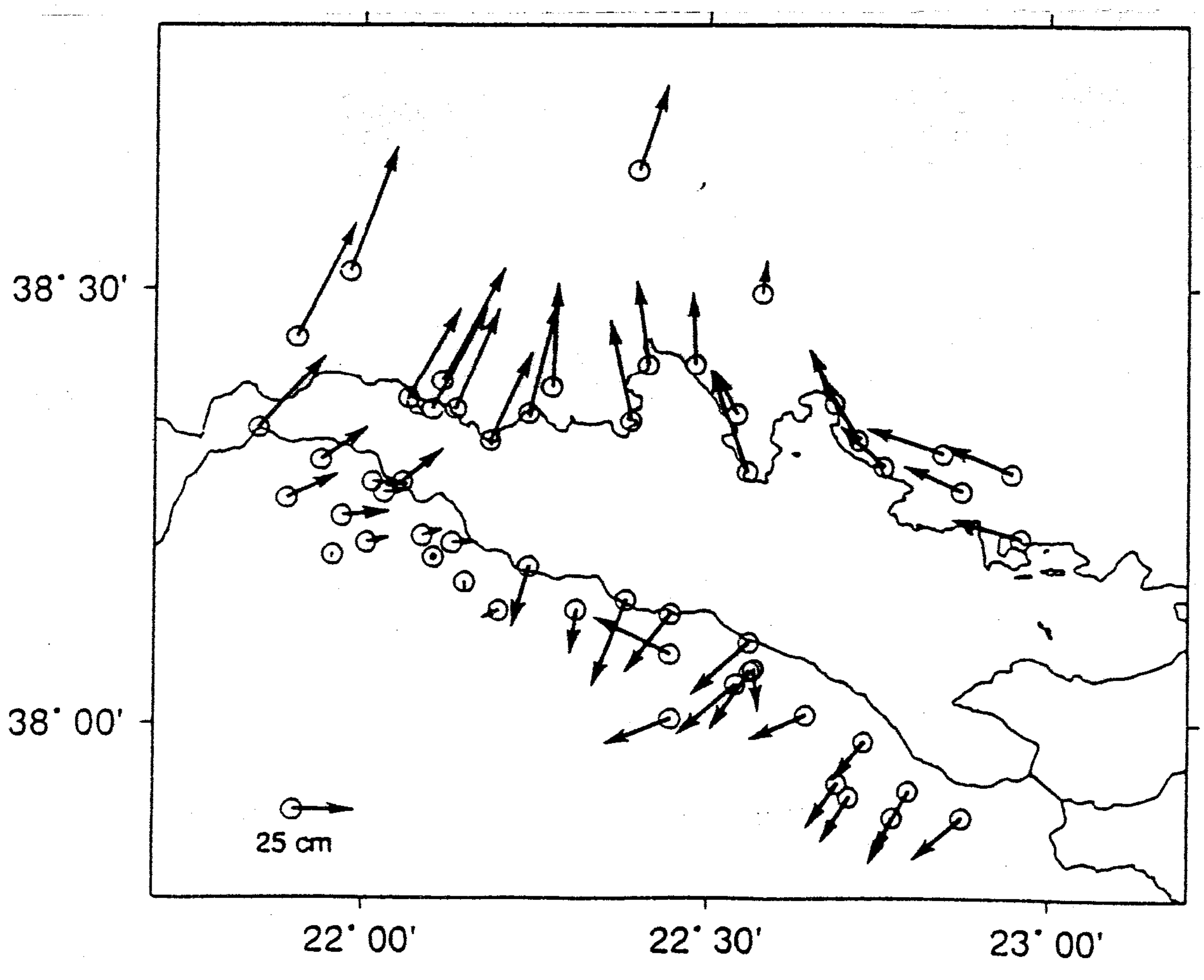


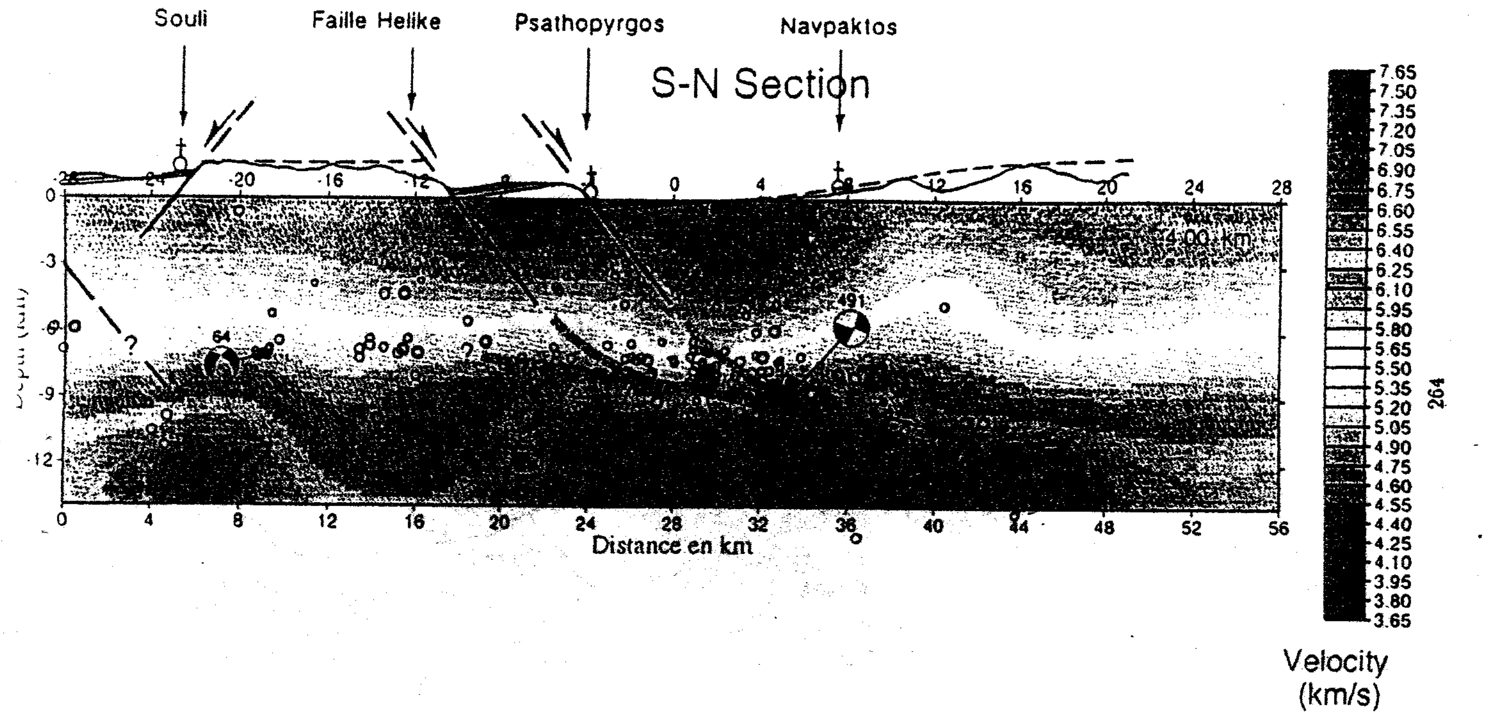
Fig 6 Principal strain in Central Greece between 1892-1992 (Davies, 1994)



Fg 7 Tectonic map of Corinth (Rigo, 1994)



Deformation observed by GPS measurements around the Gulf of Corinth (Rigo, 1994)



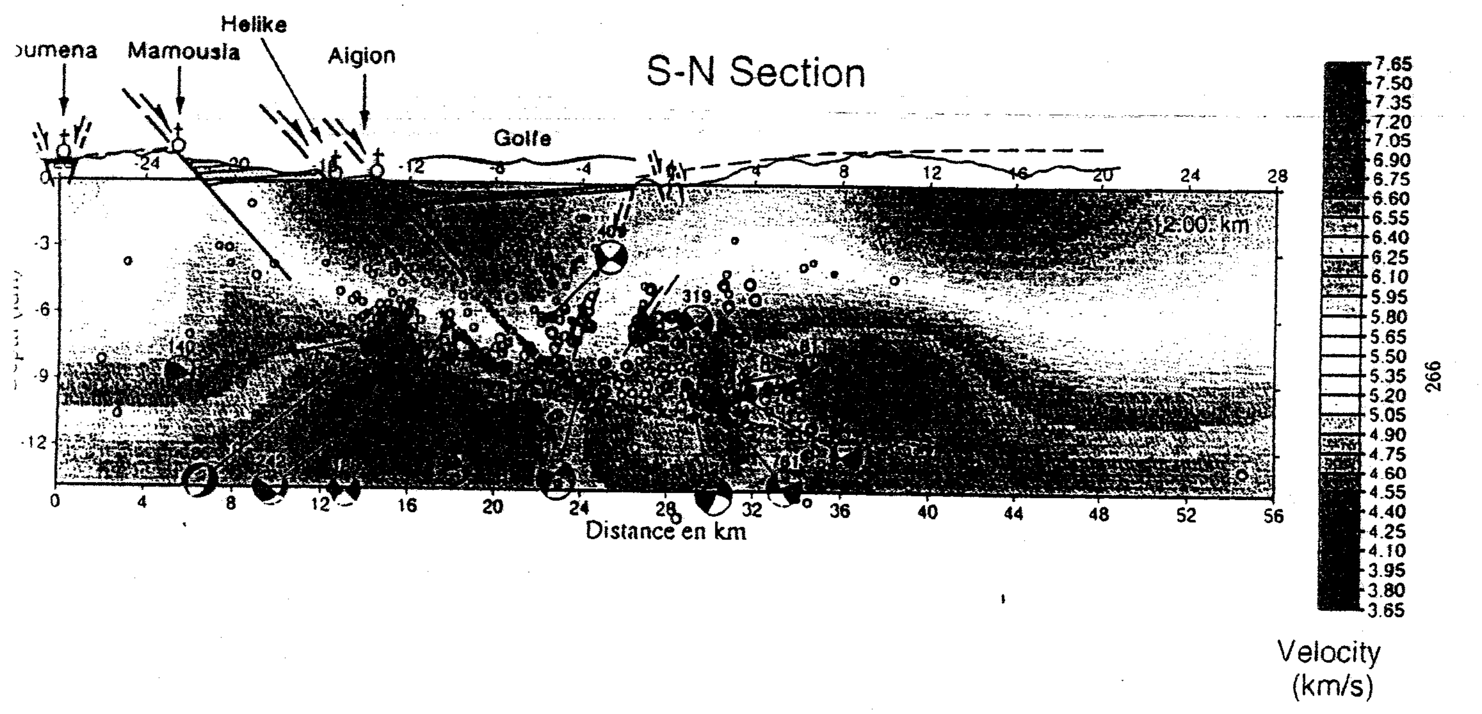


Fig8 **Two sections across the Gulf of Corinth. The velocity structure (Lemeur, 1994) is clearly related to the seismicity (Lyon-Caen et al., 1994) and to the tectonics (Rigo, 1994)**

Task 2, the local scale

Attiki is located between the two very active structures of the Gulf of Corinth and the Gulf of Evia. The total present motion across the two grabens is of about 1 cm/year (Fig 6), both for the Gulf of Corinth and the Gulf of Evia (Davies et al., 1994). Earthquake occur on the two structures, but we have no clear idea, neither about the related rate of seismic energy release, nor about the maximum expected magnitude. We have been extensively working (supported by EPOCH) around the Gulf of Corinth and have now a better idea on the tectonics. We do not have such information for the Gulf of Evia, and furthermore have no idea about possible connection between the two.

The Gulf of Corinth

The Gulf of Corinth is the most active tectonic feature of Greece, and one of the most active for continental tectonics in the world. It is located between continental Greece and the Peloponnese. It is an asymmetric graben which is wider on its eastern termination than around Patras and 800 deep on the southern side, and the thickness of the sediments can reach up to 1200 m. Most of the active faulting is located on the southern side of the Gulf and are E-W trending normal faults dipping toward the north. The length of these faults is of about 15-25 km, and they form an en-echelon sinistral system going from Patras to Corinth. This was an argument to suggest a maximum magnitude of Ms=6.7 for normal faulting earthquakes in this area (Roberts and Jackson, 1991). On the northern side, a few conjugate faults are dipping south.

During 1991-1993, we conducted a detailed survey of the deformation of the Gulf of Corinth (Fig 7), including tectonics, geodesy and seismology (Rigo, 1994). Tectonics studies of the active faults and marines terraces put some constraints on the timing and total extension of the deformation. The Gulf of Corinth is young (about 1 million years old) and opens at a rate of about 2.5 mm/y to 7 mm/y along several faults. Satellite geodesy showed a greater rate (about 2 cm/y) during the period of time of the measurements which does not affect a specific fault but seem rather to be distributed within the gulf. Precisely located earthquakes, recorded during a microearthquake survey involving more than 60 seismological stations during 2 month did, not show a clear relation between active faults and seismicity. The seismicity, however, dips toward the North as the active faults and could be connected to a possible zone of decollement at a depth of 8-12 km (Fig 8). This is consistent with an aftershock study that we conducted after the Galaxidi earthquake of November 1992 (Kementzetzidou et al., 1993). The crustal velocity structure was obtained after inverting travel times of local earthquakes (Lemeur, 1994) and it is remarkable that the seismicity and related decollement is located near a strong gradient at a depth of 7-8 km in the velocity structure.

The Gulf of Evia

The Gulf of Evia is less known. It is also partially asymmetric with the dominant faulting located on the SW side (Fig 9). Important active faults are located on both sides of the Gulf, in Central Greece and northern Evia, but the structure of the Gulf changes from the western part of the Gulf to the eastern part (Roberts and Jackson, 1991). To the west of the Gulf, the fault system dips toward the north. Farther east, near Arkitsa, the polarity of the graben changes and the fault system is located in Evia and dips toward the south. This resembles a twisted block and there is no evidence of any structure which could links the two half grabens. At the transition between the two systems antithetical faults are seen on the opposite side of the Gulf, and their origin is a matter of debate. They could be due to the listric shape of the fault located below the brittle-ductile transition in the crust or to the size of the blocks which require antithetical faults. Strong earthquakes can occur on these faults, but some of the faults are not visible at the earth surface and therefore, earthquakes can occur also off the visible faults.

The Atalanti fault is located in the region of the transition. This fault experienced two earthquakes of magnitude 6.5 and 6.7 in 1894, April 20 and 27 which broke part of the fault

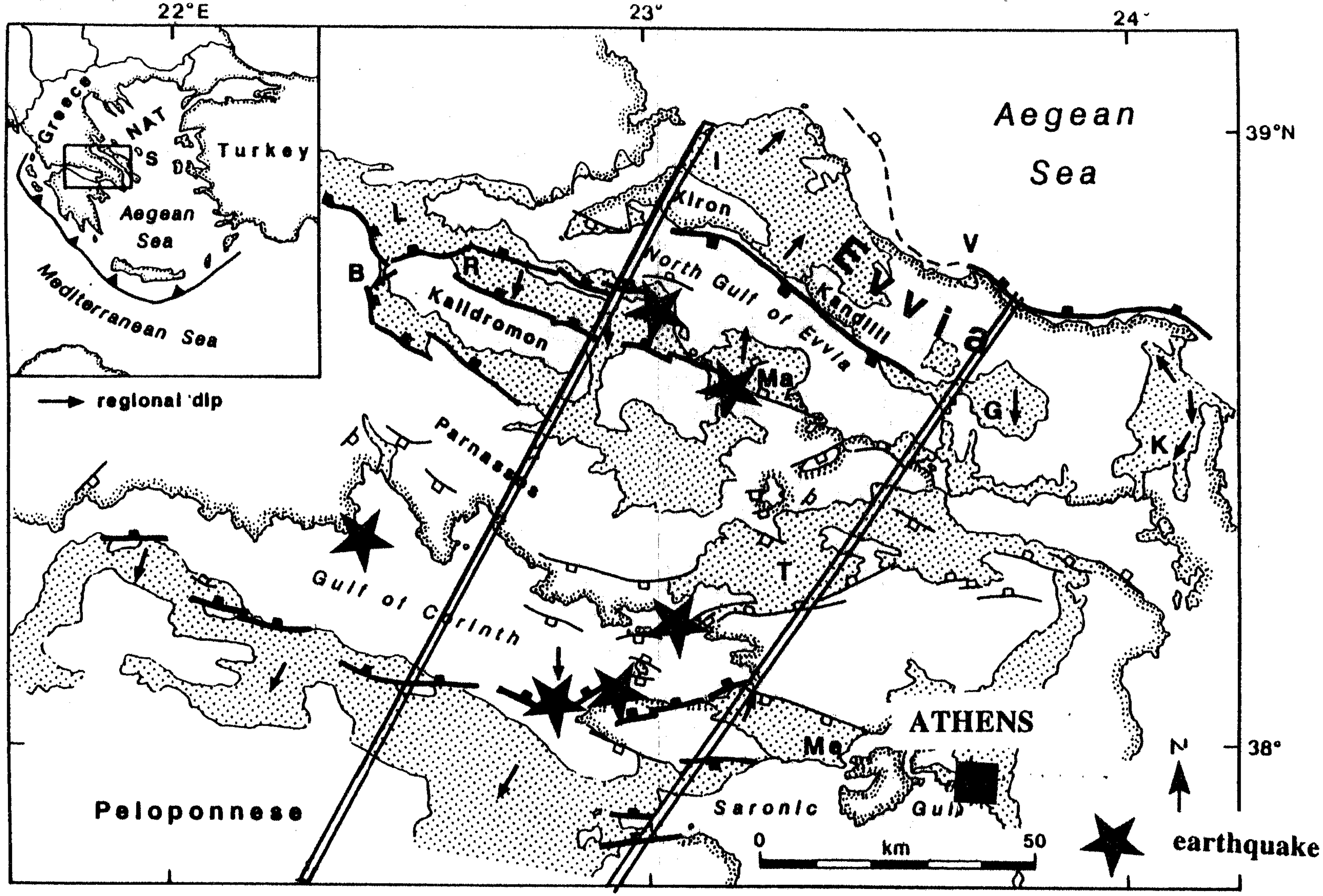


Fig 9 Tectonic map of Central Greece (Roberts & Jackson, 1991)
The 2 lines show the location of the two seismological profiles

between Atalanti and Martinon (Ambraseys and Jackson, 1990; Papazachos and Papazachou, 1989). Several hundreds of peoples were killed and many villages were destroyed. The surface breaks show clearly a normal fault with a downthrow component of about 1m. We already designed a microearthquake study in the northern part of the Gulf during an experiment around Volos in 1992. This study suggested that focal mechanisms exhibit a clear component of sinistral strike slip motion on the NNW-SSE trending faults. This is different than what is observed in the Gulf of Corinth, and may explain the difference in seismic activity.

2-1 tectonics

In 1991-1993, we have studied in details the active faults located in the southern side of the Gulf of Corinth between Patras and Corinth. We mapped the faults, studied the motion on the faults, the chronology of the motion between the different faults. We quantified very precisely the motion especially on the Xilokastro fault mapping the quaternary terraces (Fig 7).

We want to study in similar details the faults located around the Gulf of Evia. We have already a approximate view on the tectonics (Mercier et al., 1976), but we want to map more precisely the faults and quantify their displacement, using more recent techniques (satellite photos) and knowing better what is the geodynamics of the whole area. We will perform field observations around Kallidromon, Kamena Vourla and Atalanti faults, which are known to be active and seismogenic. We will also investigate Evia and south of the Gulf of Evia. We will quantify the deformation and put a time schedule on it. We will compare the tectonics around the Gulf of Evia with the tectonics around the Gulf of Corinth. We will also study the bathymetry of the Gulf of Evia, and collaborate with people from Cambridge who conducted seismic reflection profiles. These informations will put some constrains on the maximum magnitude of the earthquakes that are expected in this area.

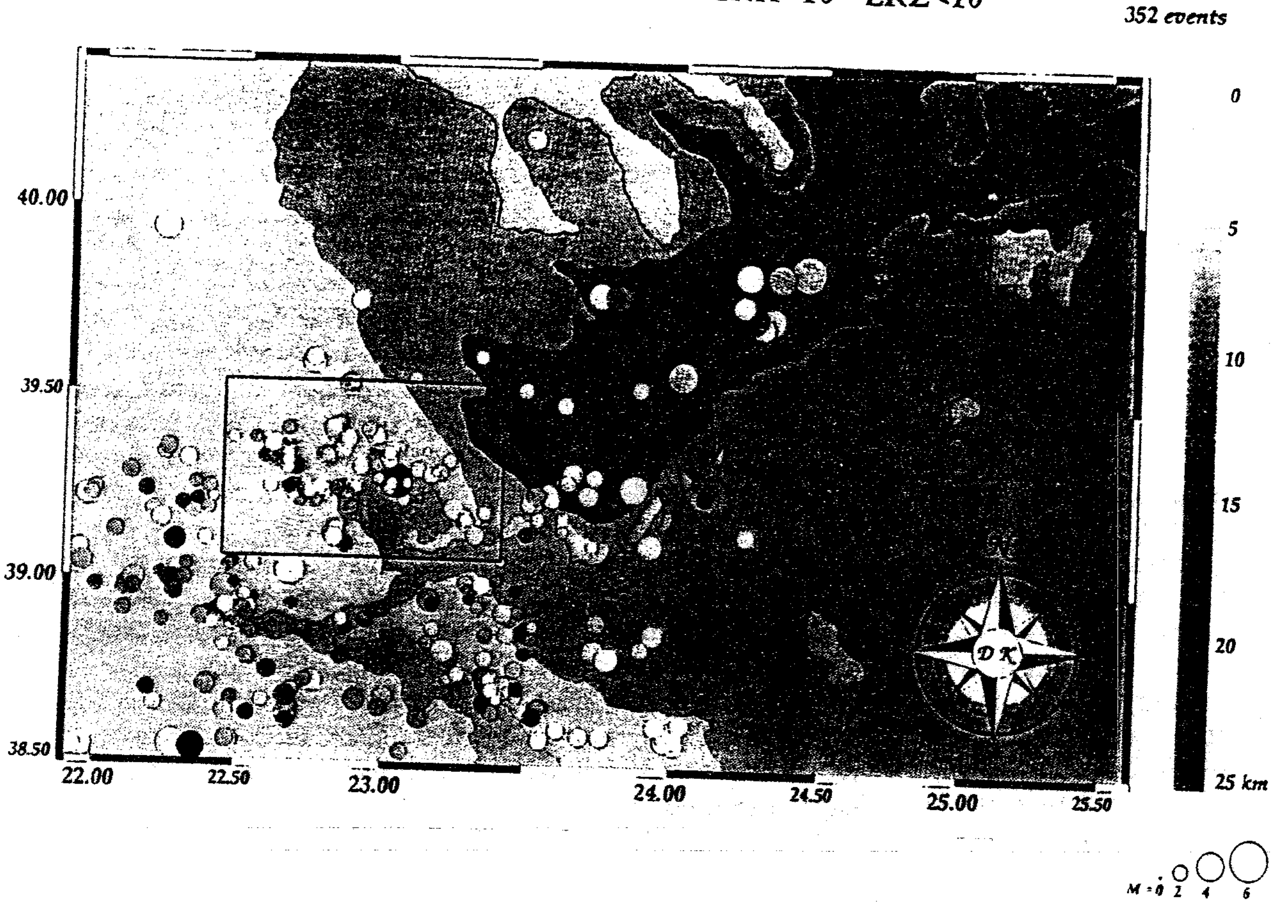
partners:

R. Armijo (IPGP) and J-C Thomas (UJF) will be in charge of the tectonics. This necessitates satellites photos, computer time, field work observations. Field observations will take about 3 man-month, processing of the satellite images 6 man-month.

2-2 geodesy

We have installed a detailed geodetic GPS network around the western part of the Gulf of Corinth. We have now a geodetic frame of about 60 benchmarks which are located better than 1 cm of precision (Fig 7). We installed our own benchmarks, but also resurveyed benchmarks that were previously installed in 1974, and that gave us good results. The displacement which was observed was greater than expected from tectonics and it is not clear if this is due to non uniform displacement after the earthquakes which occurred in 1981, or if there is a systematic misfit between tectonics and geodesy. We want to conduct a similar study across the Gulf of Evia. We will install two or three profiles across the Gulf, using old pillars that were installed several tens of years ago (a technique which was successful in the Gulf of Corinth). We want to see if the deformation is widely distributed or localized on a few active faults that could break during earthquakes. A first survey has been set in collaboration between British and Greek groups and covers widely the area (Fig 6). The results show a clear extension within Evia, Attiki and northern Peloponnese. The spacing of the stations, however does not allow to localize precisely the deformation and therefore characterize which are the active faults. To achieve this goal and know what are the most active faults at this moment (and this could be different than the pleistocene faults) it is necessary to measure the displacement across every fault with a spacing of a few kilometers. We will resurvey the benchmarks that were installed in 1967-1972, and the time duration between the 2 surveys will balance the inaccuracy of the first measurements. After 3 years we will check on a few benchmarks again with another GPS campaign. We will use the 15 Ashtech dual frequencies GPS receivers that are available from the national GPS project in France.

RMS<1.5 - nmin>4 - GAP<360 - ERH<10 - ERZ<10



Focal Mechanisms

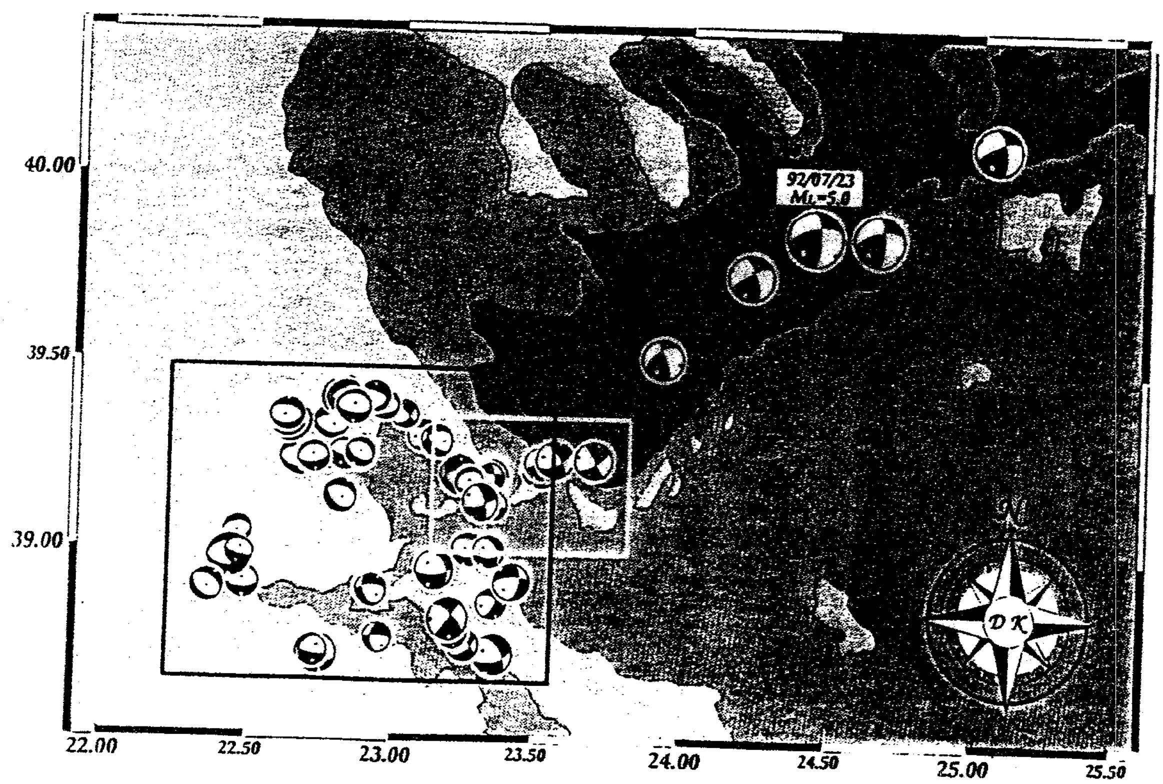


Fig 10 **Preliminary results of the experiment conducted in Central Greece.**

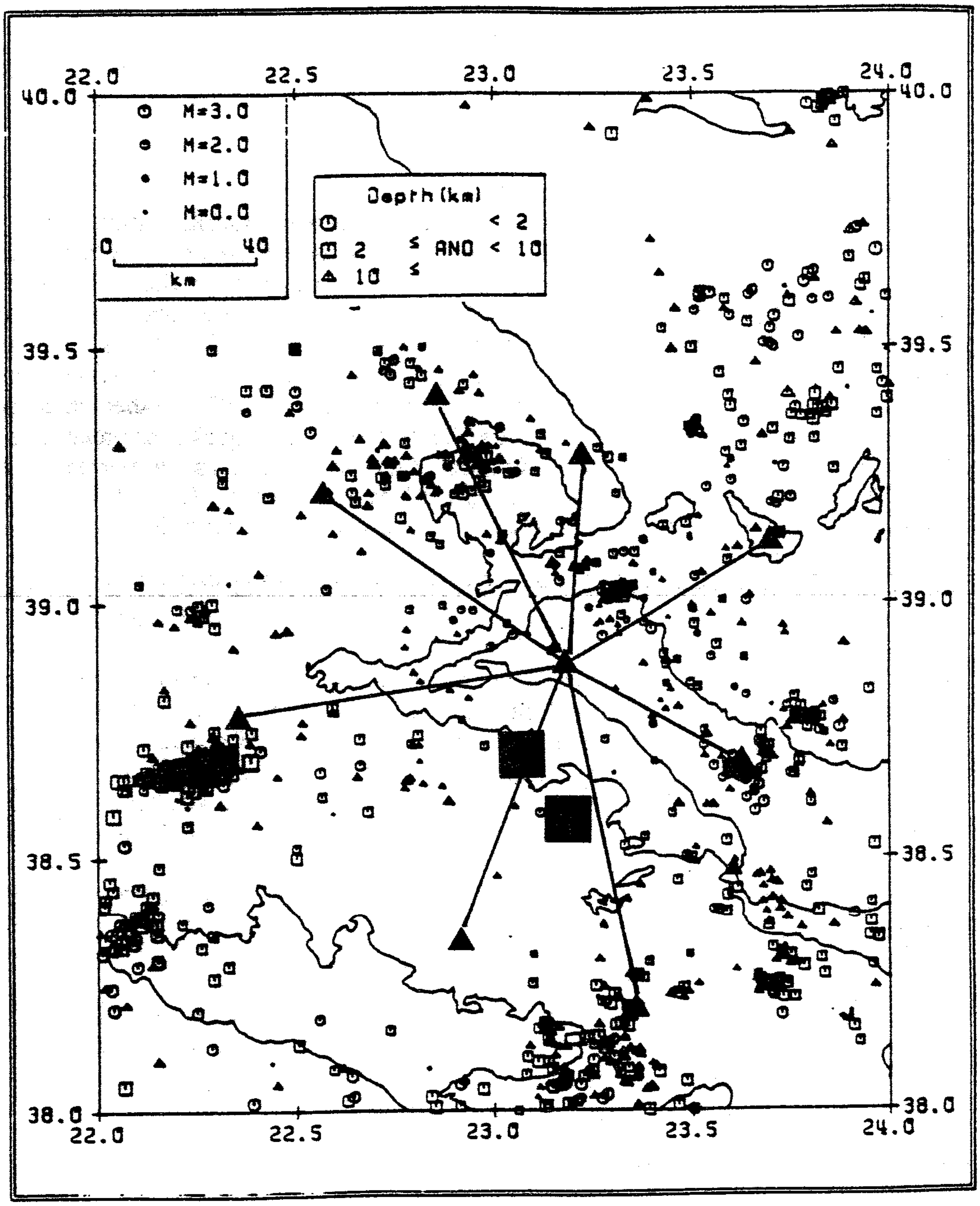


Fig 11

The seismicity recorded during one year and the VOLNET seismological network.
Squares are the 2 Atalanti earthquakes of 1894.

One large survey necessitates 15 GPS receivers during 2 weeks maintained by 15 observers. One calibration survey is twice less. We plan one large survey of about 60 benchmarks across the Gulf of Evia. We will use old benchmarks installed by the Greek-British team in the 1990's, and we will conduct 2 detailed surveys for resurvying in a few critical points with the same technique and check the old benchmarks.

partners:
J. Martinod (UJF) **and P. Briole** (IPGP) and G. Veis (NTUA) will be in charge of the geodesy. The observations will take about 13 man-month. The processing will take 12 man-month.

2-3 seismology and magnetotellurics

Around Corinth, we conducted a very detailed microearthquake survey during 2 month in 1991, and we recorded more than 3000 events. These earthquakes suggested a deepening of the faults toward the north and the connection with depth to a decollement. The focal mechanisms clearly show NS extension, but not clearly related to individual fault seen at the surface. Inversion of local earthquakes travel times provided a 3D velocity structure which clearly show a correlation with some of the active faults but also with the seismicity (Fig 8). Around Volos and northern Evia we also conducted in 1992 another microseismicity experiment, but did not record the same amount of events. Earthquakes are related to some of the active faults as the Nea-Anchialos fault near Volos. Mechanisms show normal faulting near Volos, and sinistral normal faulting of the faults located around the Gulf of Evia (Fig 10). It seems that we have two different systems of faults which behave differently in an mean regional stress pattern.

The first action is to maintain the VOLNET seismological network around the Gulf of Evia which was reinstalled with a new digital acquisition system and supported by EPOCH (Fig 11).

Because of the important amount of deformation, we suspect the lower crust and the upper mantle to be involved in the deformation process. We want to study the crustal and upper mantle structures of the system Gulf of Corinth-Gulf of Evia. We want to install two parallel profiles across the structures, from northern Peloponnese to Evia for about 4 month. We will install 40 stations of the French Lithoscope seismological network. The sensors are 5 seconds seismometers digitized on 24 bits, the recording is continuous on DAT cassettes and allows about 1 month of recording between visits. Each profile will be of 20 3-D seismological stations with a spacing between stations of 10 km. We will record local earthquakes and distant earthquakes, and use travel time residuals, attenuation and source receiver functions to study the velocity structure of the crust and upper mantle. We will also study anisotropy which could be related to flow in the upper mantle.

In addition to the seismological study we will conduct a magneto-telluric profile located at the same place which will help to precise the geometry of the structure and the location of deep rooted faults. Magneto-tellurics is a non-expensive method to precise discontinuities in the crust. Instrumentation is available in Athens and we will perform a survey at the same location as the seismological survey.

partners:
K. Makropoulos (NKUA.SL) will maintain the permanent VOLNET network around the Gulf of Evia.
H. Lyon-Caen (IPGP), D. Hatzfeld (UJF), K. Makropoulos (NKUA.SL), E. Papadimitriou (AUTH), and G. Karakaisis will take the temporary experiment in charge. The experiment will take about 16 man-month, the processing of the data about 24 man-month. The equipment will be partly the seismological stations of the French Lithoscope program and partly some equipment that will be acquired during the project.

E. Tsanis will perform the magneto-telluric observations at the same place as the seismological profiles.

2-4 Modeling

The objectives are to describe the Evia fault system in the same details as the Corinth fault system, to compare them and to look for possible interconnection between the two systems. This is the reason to investigate for the deep structure and look for possible interaction between the two. The long term (tectonics) motion is smaller than the short term (GPS) motion. For seismic hazard it is important to understand the mechanics and the dynamics of such system of faults. Is the motion discontinuous in the Aegean, or only on one fault? Are the motion on different faults synchronous or alternate? Can the motion on one fault trigger an earthquake on a neighbor fault? These are the questions that we want to adress.

partners:
J. Martinod (UJF) and P. Briole (IPGP). This needs only computer time and man power and will take about 6 man-month.

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3) PROJECT MILESTONES AND DELIVERABLES

This proposal is mainly devoted to scientific research and implication for seismic hazard mitigation. It does not provide products or consumer goods. But the different experiments will provide an important amount of new data, manily in seismology and geodesy. These data will be released to every scientific institutions after the end of the project. This is the policy that we adopted for the previous projects and which increases significantly the value of our effort. We are confident that the data, as for the previous data, will be used by other scientists.

Most of the results during the project will be reports or, what is more valuable to us, papers published in scientific journals. We identify for the different projects the following milestones and deliverables.

Tectonics:
Milestones: Satellite images, tectonics maps
Contract deliverables: report every year
Technical deliverables: tectonic interpretation

Geodesy:
Milestones: map of the benchmarks, geometry of the network
Contract deliverables: report every year
Technical deliverables: distances between benchmarks. Deformation pattern between benchmarks.

Seismology:
Milestones: maps of the seismological stations, earthquakes catalogs, seismological records catalogs
Contract deliverables: report every year
Technical deliverables: seismicity maps, focal mechanisms, velocity structure, attenuation structure, anisotropy structure, relation with surface faults

Modeling:
Milestones: computer codes
Contract deliverables: report every year
Technical deliverables: map of elastic response to the fault interaction

No restriction to any deliverable

4) BENEFITS

The benefits of refining seismic hazard assessments are obvious if not fast. At this moment, earthquake prediction is not a efficient method, and on the other hand seismic hazard mitigation is more efficient in better understanding the different processes of the "seismic cycle" and the parameters important for the seismic waves propagation. Some of the topics are techniques can be applied on a routine basis, they mostly concern what is related to the local conditions which influence the spectral characteristics of the ground motion. Some other are half the way from scientific research, this is what is related to the "seismic cycle", the source processes, and the deep structure and attenuation. Our proposal will help in the characterization of a few parameters which are necessary to know if one wants to reduce seismic hazard: identification of active faults, processes involved to built an earthquake, relation between shallow and deep structures, parameters important for wave propagation and ground motion.

Attiki is located between the two systems of the Gulf of Corinth and Gulf of Evia. To understand the processes that are involved and to look for possible interaction between faults is crucial for seismic hazard mitigation around Athens. Two dense seismological networks (VOLNET and CORNET) are, at this time, in operation on both sides of Attiki and will provide accurate data about the location of the earthquakes. The geodetic and tectonic measurements will quantify the total deformation, and constrain the possible models for the mechanism involved in the active faulting. This information with the information on the attenuation structure in Attiki is necessary for civil engineers to design structures.

The Aegean sea is not a very seismic area as in Japan or the Pacific area, but very large and destructive earthquakes occurred in the past and generated important tsunamis. The knowledge of the active regions, the type of faulting, the attenuation law, will help in better predicting the ground motion during a big earthquake and the possible tsunamis. Furthermore we do not know very much about intermediate depth activity.

Studies about seismic hazard in Europe need to gather an important amount of data that will be the input in numerical modeling. Greece is the country in western Europe that experience the highest level of seismicity and therefore is a good place to gather data and test methods. Experimental seismology need to deploy a very important amount of seismological stations and no institution can provide such amount of instruments, and such amount of people to maintain the instruments, and the necessary budget. Such studies are necessarily common projects between different countries and the collaboration is efficient when supported by European Community programs as it was done before. Moreover, western Europe is a region of moderate seismicity and return periods of strong earthquakes can be of several thousands years. But we know that most of these European countries of the European Community have been affected by destructive earthquakes during historical time. The experience that we will gain in Greece will be useful in other European countries.

5) ECONOMIC AND SOCIAL IMPACTS

Destructive earthquakes are not only the earthquakes of magnitude greater than 7 that make a big city to collapse. Earthquake of magnitude 5, if shallow and close to buildings, can induce enough damages which make necessary to rehabilitate them. The economic cost of a magnitude 5 earthquake is therefore not negligible if it is badly situated beneath a urban zone. A better knowledge of the seismic sources and of the ground motion helps in refining the antiseismic codes.

But also the social impact of an earthquake depend on the estimate of the damages after a earthquake. The traffic, the lifelines, the fire can induce panic in the population, and a good estimate of the ground motion during an earthquake can help in reducing the impact of the damages. The effect of a tsunami, if more rare, will be also important, and a good estimate of the amplitude of the tsunami is important.

Our study will help in understanding the mechanisms which creates earthquakes on both sides of Attiki (there is still a controversy about the maximum magnitude that can be expected) and, therefore, it will help in reducing the seismic hazard around Athens.

It will help in mapping the seismogenic zones and the type of tectonics in the Aegean sea, and improve the computation of the expected ground motion during earthquakes, especially of intermediate depth.

6) PROJECT MANAGEMENT STRUCTURE

For the last 10 years we have been working systematically in the Aegean. We studied the earthquakes listed routinely in bulletins, and computed mechanisms using body wave modeling. We conducted several microearthquake studies to improve significantly the accuracy of the location of the earthquakes, compute more mechanisms and relate them to active faulting. We mapped active faults and measured the deformation by satellite geodesy. In some places we studied the ground motion in relation with the geotechnical parameters. We have now a better and more precise picture of the deformation pattern and the inferred associated seismic hazard. We have a very good and fruitful collaboration, and we know how to manage large field experiments and data processing.

Every year we will have a common meeting between the participants

1) Year 1

The first year, we will conduct the seismological study of the Aegean sea and install the network of 30 seismological stations. We have already some practice in installing such a network, and we have already been the Cyclades and Dodecanese islands.
In the same time we will start tectonic observations in the field and on satellite images.
Finally we will start the geodetic measurements across the Gulf of Evia.

We will write a first report showing 1) for seismology a catalog of the recorded events and the records that we obtained 2) for geodesy a map with the GPS benchmarks.
We will publish a advertising leaflet explaining our project.

2) Year 2

The second year, we will focus on the study of the Gulf of Evia. We will install again 40 3D-digital stations for 4 month along two profiles across the 2 gulfs from northern Peloponnese to Evia and record local earthquakes and distant earthquakes.
We will perform magneto-telluric observations along the 2 seismological profiles.
We will again go in the field for tectonics.
We will have the preliminary results about satellite geodesy in comparing the old pillars with the new GPS measurements.
We should have some processing of the data for the Aegean experiment (seismicity map and focal mechanisms).

We will write a second report with a first processing of the seismological data, specially a seismicity map and focal mechanisms. We will have the first results related to the velocity structure and anisotropy.

3) Year 3

The third year, we will interpret the data and publish preliminary results. We will go to resurvey part of the geodetic network to check that the measurements between existing pillars give the same results as between 2 GPS campaigns.

We will write the third report with a map of deformation obtained by satellite geodesy, results on the velocity structure and attenuation.

TIME TABLE

	year 1				year 2				year 3			
Aegean seismology 1												
Experiment	xxx	xxx										
Processing 1-1,1-3,1-4			xxx	xxx	xxx	xxx	xxx	xxx				
Results									xxx	xxx	xxx	xxx
Tectonics 2-1												
Observations	x					x						
Processing		xxx	xxx	xxx			xxx	xxx				
Results					xxx				xxx	xxx		
Geodesy 2-2												
Observations			x				x			x		
processing				xxx	xxx			xxx			xxx	
Results						xxx			xxx			xxx
Evia seismology 2-3												
Experiment 2-3-2				xxx	xxx							
Processing 2-3-3						xxx	xxx	xxx	xxx			
Results										xxx	xxx	xxx
Magneto-tellurics 2-3-2												
Observations					x							
Processing						xxx						
Results							xxx					
Modeling 2-4											xxx	xxx

MAN-MONTH POWER DISTRIBUTION

	UJF	IPGP	NKUA	AUTH	NTUA	UCAMB	Total
task 1 Seismology observations	7	7	8	8		4	34
task 1-1 Shallow tectonics	4		4	4			12
task 1-2 Tsunamis		2		4			6
task 1-3 Structure	12	6	6	6		6	36
task 1-4 Subduction	4		4	4			12
task 2-1 Tectonics	5	4					9
task 2-2 Geodesy	8	8			9		25
task 2-3-1 VOLNET			2				2
task 2-3-2 Observations	4	4	4	4			16
task 2-3-3 Processing	6	6	6	6			24
task 2-4 Modeling	3	3					6
Total	53	40	34	36	9	10	**182**

7) THE PARTNERSHIP

The project will be managed by six laboratories which belong to six different universities and three countries. We know each other for a long time and are used to meet frequently either in Greece or in France. We already have PhD-students with common advisers in both countries. We have a good practice on scientific collaboration.

In each institution several senior scientists will be involved in the projects with different responsibilities. We started our collaboration between Greece and France in 1984. Our collaboration was mostly devoted to seismic hazard, seismotectonics, and seismic precursors and was funded by several programs of the E.C. Since the beginning of the collaboration we conducted many field works together, installing, for 2 month periods of time, up to 100 portable seismological stations. We worked in several regions of Greece (Macedonia, Peloponnese, Crete, Western and Central Greece, Corinth). We improved significantly the location of the earthquakes, their relation with active faults, and therefore the seismic hazard assessment. We also installed a permanent seismological network around the Gulf of Corinth (CORNET) and restarted the VOLNET around the Gulf of Evia. We worked on ground motion either around Volos, Patras, Thessaloniki. We worked around Thessaloniki, identified active faults near the city, performed a microzonation study and worked on the amplification of the ground motion due to local conditions. We worked on systematic studies on the effect of topographies on the ground motion. We also worked on the "empirical Green function method" which allow to use small earthquakes to predict the ground motion in case of strong earthquakes. We focused on the Gulf of Corinth and provided quantitative informations about the total deformation by satellite GPS geodesy, the timing of the deformation and the geometry of active faults. The collaboration involved the University of Paris (IPGP) and University of Grenoble (UJF), the Aristotelian University of Thessaloniki (AUTH), the University of Athens (NKUA.SL), the National Observatory, the National Technical University of Athens (NTU), and the University of Cambridge (UCAMB) . For some projects either, we had collaborations with other institutions in Great Britain, Germany, Italy, Belgium, Spain and Portugal. These collaborations were successful and provided a huge amount of new data related to seismic hazard.

The present project is presented by three countries (France, Greece, and Great Britain) and six laboratories. The reason is that we want to propose an efficient collaboration with a moderate budget. Most of our budget is for field and travel expenses, only little money will pay equipment or salaries.

Partner 1, the University Joseph Fourier of Grenoble, France (UJF)

D. Hatzfeld (Research Director) will be the "Project Coordinator". He has been involved in studies about seismotectonics and seismic hazard in the Aegean for the last ten years. He has been already project coordinator for the projects that were conducted during 1986-1989 and supported by the EC. He will be responsible for UJF. He will also be in charge of the Aegean seismological network, in collaboration with IPGP, AUTH, NKUA.SL, and UCAMB. He has been already in charge of installing such networks during 7 previous experiments, deploying more than 100 instruments in the field and involving more than 50 observers. He will coordinate the scientific exploitation of the data related to the Aegean sea. He will participate in the Attiki seismological profile.
The French "Lithoscope" national program will provide the 40 3D-digital seismological stations with continuous data-loggers.

J. Martinod (Assistant Professor) will be in charge of the GPS observations around Evia in collaboration with IPGP and NTUA. He already participated in several GPS surveys and designed a GPS survey around Thessaloniki. He is involved in numerical modeling.
The French "GPS project" will provide the 15 GPS Ashtech dual-frequency receivers that are available in France.

J-C. Thomas (Assistant Professor) will participate in the tectonic observations around Evia. His actual field is related to tectonics and paleomagnetism in Asia.

Recent publications relevant to the project

Hatzfeld, D., Besnard, M., Makropoulos, K., Voulgaris, N., Kouskouna, V., Hatzidimitriou, P., Panagiotopoulos, D., Karakaisis, G., Deschamps, A., & Lyon-Caen, H., (1993), Subcrustal microearthquake seismicity and fault plane solutions beneath the Hellenic arc, *J. Geophys. Res.*, **98**, 9861-9870.

Hatzfeld, D., Besnard, M., Makropoulos, K., & Hatzidimitriou, P., (1993), Microearthquake seismicity and fault plane solutions in the southern Aegean and its geodynamics implications, *Geophys. J. Int.*, **115**, 799-818.

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Hatzfeld, D., Kassaras, I, Panagiotopoulos, D., Amorese, D., Makropoulos, K., Karakaisis, G., & Coutant, O., (1994), Microseismicity and strain pattern in Northwestern Greece, *Tectonics*, in press.

Partner 2, the Institut De Physique du Globe de Paris, France (IPGP)

H. Lyon-Caen is responsible for IPGP. She devoted most of her time during the last years to study seimotectonics and seismic cycle in the Aegean. She will be in charge of seismological profile across Attiki with the collaboration of AUTH, NKUA.SL and UJF. She has been "Project Coordinator" for the previous EPOCH-project around Corinth supported by the EC. The French "Lithoscope program" will provide the 40 3D-digital seismological stations.

P. Briole has a good experience in GPS measurements. He will organize the GPS measurements across Evia. He has been previously in charge of the GPS measurements around the Gulf of Corinth and the Aegean sea.

R. Armijo is one specialist in active tectonics. He has been involved in tectonics of Asia and South America. He will be in charge of the tectonic observations. He will provide the satellite photos. He has been in charge of the tectonics around Corinth during the EPOCH program.

Recent publications relevant to the project

Chabalier de, J.B., Lyon-Caen, H., Zollo, A., Deschamps, A., Bernard, P., & Hatzfeld, D., (1992), A detailed analysis of microearthquakes in western Crete from digital three-component seismograms, *Geophys. J. Int.*, **110**, 347-360.

Lyon-Caen, H., et al., 1988, The 1986 Kalamata (South Peloponnesus) Earthqauke: Detailed Study of a Normal Fault, Evidences for East-West Extension in the Hellenic Arc, *J. Geophys. Res.*, **93**, 14967-15000.

Armijo, R., Lyon-Caen, H., & Papanastassiou, D., 1991, A possible normal-fault rupture for the 464 BC Sparta earthquake, *Nature*, **351**, 137-139.

Briole, P., Ruegg, J-C., Lyon-Caen, H., Rigo, A., Papazissi, K., Hatzfeld, D., and Deschamps, A., 1994, Active deformation of the Gulf of Corinth, Greece: results of repeated GPS surveys between 1990 and 1993, *Ann. Geophys.*, **12**, c65.

Lyon-Caen, H., Armijo, R., Briole, P., Rigo, A., Ruegg, J-C., Papazissi, K., Veis, G., Makropoulos, K., Papadimitriou, P., Hatzfeld, D., Deschamps, A., 1994, Seismotectonics and Defromation of the Gulf of Corinth, EOS, *AGU Spring meeting*, invited paper.

Partner 3, The National Kapodistrian University of Athens Seismological Laboratory, Greece (NKUA.SL)

The Seismological Laboratory of University of will contribute to the project by:

- Maintaining the existing VOLNET network (9 stations) located around the Gulf of Evia, collecting and analysing the data.
- Maintaining the existing CORNET telemetric digital network (5 3-component stations) located around the eastern part of Gulf of Corinth, collecting and analysing the data. Both networks will run with different parameter configurations according to the needs of each project activity.
- Participating in the two seismological experiments (Gulf of Evia and Aegean sea), by field reconnaissance, deployment of instruments and field missions.
- Participating, in close collaboration with the other partners in the processing and analysis of the data obtained from both experiments.

Experience of the organization and responsible scientists

The Seismological Laboratory with Prof. K. Makropoulos as the responsible scientist has been involved for several years in relative studies through EU, UN and National projects. For the last eight years, Prof. K. Makropoulos and his collaborators in the Laboratory have been working in hazard, microzoning, field local network installation and data analysis for both seismotectonic and site specific studies. The Seismological Laboratory is presently operating two permanent digital telemetric seismic networks (VOLNET, CORNET), and with its own digital instruments is performing field experiments almost every year.

Relevant Publications

1. Kouskouna, V., Makropoulos, K.C., Voulgaris, N. and Drakopoulos, J., 1993. Qualitative study of site effects on seismograms - a case study in the area of Eastern-Central Greece. Comprehensive approach to Earthquake Disaster Mitigation, Vogel-Ergunay (Eds), 119-130.

2. Kouskouna, V., Makropoulos, K.C. and Drakopoulos, J., 1993. Determination of source parameters from seismic spectra in Central Greece. 2nd International Geophysical Congress, Florina, Greece, v1, 248-263.

3. Makropoulos, K.C., Diagourtas, D., Voulgaris, N., Gariel, J.C., Dervin, P., Hatzfeld, D., Wajeman, N., 1993. The western part of Gulf Corinth (Greece) strong motion network (RASMON). Preliminary results. 2nd International Geophysical Congress, Florina, Greece, v1, 460-471.

4. Ziazia, M., Makropoulos, K.C., Papadimitriou, P., Kementzetzidou, D., Hatzfeld, D., Hatzidimitriou, P., Panagiotopoulos D., Karakaisis, G., 1994. A microseismicity survey in central Greece (Volos): Results and discussion, ESC XXIV General Assembly, Athens 1994, pp.12 (in press).

5. Voulgaris, N., Drakatos, G., Makropoulos, K.C., Drakopoulos, J., 1994. 3-D velocity structure in northern Peloponessus (Greece) from inversion of focal earthquake arrival times, ESC XXIV General Assembly, Athens 1994, pp. 10 (in press).

Partner 4, the Aristotelian University of Thessaloniki, Greece (AUTH)

The research activity of the AUTHconcerns seismic hazard assessment, seismic zonation, time dependent hazard, crustal and upper mantle structure and attenuation of seismic waves, source properties of the earthquakes, seismotectonics, long term earthquake prediction, historical seismicity. The results of this research have been published in well known geophysical journals. The scientific personnel of AUT is extensively experienced in the operation of advanced geophysical instruments as well as in running and maintaining the telemetric seismological network operated by AUT since 1980.

The responsible scientist, (Prof. Basil Papazachos) is well known in the national and international geophysical community for his extensive contribution to the solution of many problems related to seismic hazard and earthquake prediction. The scientific personnel of the AUT (Assoc. Prof. A. Kiratzi, Assoc. Prof. P. Hatzidimitriou, Assoc. Prof. G. Karakaisis, Assoc. Prof. E. Papadimitriou, Assist. Prof. D. Panagiotopoulos) will contribute to the accomplishment of the undertaken tasks. In addition, a lot of work will be done by the scientific personnel of the Seismological Station (the seismologists Dr. C. Papaioannou, Dr. E. Scordilis, Dr. B. Karacostas) who have longstanding experience in seismological networks and computing. Finally, Dr. C. Papazachos, a seismologist cooperating with AUT will also contribute to the accomplishment of the undertaken tasks.

Recent publications relevant to the project

Hatzidimitriou, P. M., 1995, S-wave attenuation in northern Greece, *Bull. Seism. Soc. Am.*, in press.

Papazachos, B. C., Hatzidimitriou, P., Karakaisis, G., Papazachos, C., and Tsokas, G., 1993, Rupture zones and active crustal deofmation in southern Thessalia, Central Greece, *Boll. di Geof. Teor. e Applicata*, **35**, 363-374.

Papazachos, C., 1992, Anisotropic radiation structure of the upper crust in Greece, *Pageoph*, **138**, 445-469.

Papazachos, C., and Kiratzi, A., 1995, A detailed study of the active crustal deformation in the Aegean and surrounding area, *Tectonophysics*, in press.

Papazachos, C. B., Hatzidimitriou, P. M., Panagiotopoulos, D. G., and Tsokas, G. N., 1995, Tomography of the crust and upper mantle in SE Europe, *J. Geophys. Res.*, in press.

Partner 5, the National Technical University, Greece (NTUA)

1. Contribution

a) HGL will provide available positional information for the already established network in the vicinity of the gulf of Evia.

b) The NTU group, together with the other groups, will carry out both the reconnaissance, in order to choose the pillars from the already existing Helllenic trigonometric network, as well as the GPS measurements decided.

c) In collaboration with other groups, it will carry out the processing analysis and interpretation of the various data.

2. Coordination - experience

The contribution to the proposed activities from the NTUA scientists will be coordinated by Prof. George Veis.
Other main participants in the team are Prof. Harilaos Billiris expert of GPS and classical geodetic techniques, Assistant Prof. Kalliope Papazissi and Assist Prof. Christiana Mitsakaki expert on geodetic computations and analysis.

The group of scientists at DSO and HGL have an extended experience in organising and executing large GPS projects and in processing and analyzing of GPS observations for crustal deformation studies.

References

1. H. Billiris, D. Parasissis, G.Veis, P. England, W.Featherstone, B. Parsons, P. Cross, P. rands, M.Rayson, P. Sellers, V. Ashkenazi, M. Dacison, J. Jackson and N. Ambraseus.
"Geodetic determination of tectonic deformation in Central Greece from 1900 to 1988".
Nature Vol. 350 No 6314 pp 124-129, 14th March 1991

2. A.Rigo, P. Briole, H. Lyon-Caen, J.C. Ruegg, A.M. Agatza-Balodimou, G. Veis, K. Papazissi, X. Mitsakaki, K. Makropoulos.
"Deformation studies in the Western part of the Gulf of Coringth (Greece), first results from GPS campaign, accuracy and comparison with Triangulation data".
"2nd Congress of the Hellenic Geophysical Union" Florina 5-7 May 1993. Greece

3 A.M.Agatza-Balodimou, P. Briole, H.Lyon-Caen, C.Mitsakaki,A. Rigo, J.C. Ruegg, K.Papazissi, G.Veis.
"Recent Developments in Deformations studies from Geodetic Data in the Corinthian Gulf (Greece).
1st Turkish International Symposium on Deformations Istanbul, September 1994.

4 P. Clarke, A. Curtis, I.Galanis, H.Billiris, P.England, D. Paradissis, B. Parson, G.Veis
"Geodetic Studies of strain accumulation and release during the seismic cycle: Results from the gulfs of Korinthos and Argos
1st Turkish International Symposium on Deformations Istanbul, September 1994

5. G. Veis, H.Billiris, B.Nakos, D. Paradissis
"Tectonic Strain in Greece from geodetic measurements"
Annales of the Academy of Athens, Vol. 76, p. 129-166, Greece (1992).

Partner 6, the University of Cambridge, Great Britain (UCAMB)

K. Priestley is Assistant Director of Research at the University of Cambridge. He has been involved in projects related to the study of velocity structure using sophisticated techniques in North America and in Asia. He also has been working on attenuation and anisotropy using broad band seismograms.
In collaboration with the University of Athens (NKUA-SL) he installed a network of broad band instruments in the Peloponnese. In collaboration with the Technical University of Istanbul he installed another network in Turkey.
K. Priestley will participate in the field experiment in the Aegean. He will process the data for velocity structure and anisotropy.

Recent publications relevant to the project

Priestley, K.F., Cipar, J., Egorkin, A.V., and Pavlenkova, 1994, Upper mantle velocity structure beneath the Siberian plateform, *Geophys. J. Int.*, **118**, 369-378.

Smith, K.D., Brune, J.N., and Priestley, K.F., 1991, The seismic spectrumradiated energy, and the Savage and Wood inequality for complex earthquakes, *Tectonophysics*, **188**, 303-320.

Gomberg, J.S., Priestley, K.F., and Brune J.N., 1989, The compressional velocity structure of the crust and upper mantle of Northern Mexico and the Border region, *Bull. Seism. Soc. Am.*, **79**, 1496-1519.

Priestley, K.F., Zandt, G., and Randall, G.E., 1988, Crustal structure in Eastern Kazakh, USSR, from teleseismic receiver functions, *Geophys. Res. Lett.*, **15**, 613-616.

Chavez, D.E., and Priestley, K.F., 1986, Measurement of frequency dependant Lg attenuation in the Great Basin, *Geophys. Res. Lett.*, **13**, 551-554.

8) FINANCIAL INFORMATION

	UJF	IPGP	NKUASL	AUTH	NTUA	UCAMB	Total
personnel	5.00	0.00	10.80	6.00	0.00	0.00	21.80
travel & subsistence	55.00	80.00	34.72	33.00	25.00	8.77	236.49
durable equipment	20.00	15.00	0.00	10.00	0.00	0.00	45.00
consumables	20.00	20.00	10.73	7.25	3.08	3.73	64.79
computing services	0.00	0.00	0.00	0.00	0.00	0.00	00.00
other costs overhead	15.00	0.00	11.25	11.25	5.62	2.50	45.62
Total	115.00	115.00	67.50	67.50	33.70	15.00	**413.70**

Personnel represents support for 4 post-doc or students for a total of 27 month. They will be directly involved in the experiment.

Most of our expenses are related to field work. We ask money to design experiments, go in the field and gather data.

Per-diem for 66 man-month =2000 days x 50 ECU/day	100.0 kECU
Travels to Greece, 72 trips x 600 ECU	43.2 kECU
Travels in Greece, 174 trips x 250 ECU/trip	43.5 kECU
Renting cars 25 month x 800 ECU/month	20.0 kECU
3 Meetings x 10 scientists x 850 ECU	25.5 kECU
1 Meeting for organistaion 5 scientists x 850 ECU	4.3 kECU

Durable equipment is necessary for completing the equipment that is already available but in some case not adapted to a long term experiment (autonomy and time correction). We ask for a 3 years project, the 40% complement money will be provided by each institution on his own ressources.

Consumables are necessary to maintain the instruments in the field for about 1 year in total (batteries, petrol, DAT-cassettes, maps, tools...)

The total cost of the different tasks including personnel, field work, equipment and consumables

Task 1, seismology in the Aegean	184.2 kECU
Task 2-1, tectonics in Evia is	19.3 kECU
Task 2-2, geodesy in Evia is	96.7 kECU
Task 2-3, seismology in Evia	113.5 kECU

9) EXPLOITATION PLANS

All of us devote most of our time on the geodynamics, the tectonics, the geodesy, the seismology and associated seismic hazard in Greece, so the project of this proposal is definitely our first priority for the next years. We are used to collaborate together and this collaboration was successful both in terms of human relations and in terms of scintific outcome. We already defined rules which are efficient for our collaboration.

Tectonics:
We share the cost of satellite photos, go in the field together, communicate our results.
Geodesy:
We define the geometry of the GPS network together with tectonicists and seismologists. We collaborate in the field, exchange the raw data, process them separately for check and combine our results
Seismology:
We go in the field together, share the records, process the data separately and combine the results together.
Modeling:
Modeling is performed in collaboration with the 3 other tasks by people who have been involved in one of the task.

All the data are available to any partner during the project. After a certain period of time, which is of 2-3 years, to give the students the possibility of making a PhD-thesis, all the data are released to anyone who ask them. The only constrain is to acknowledge the support and the origin of the data. This policy is our policy for the last 10 years, and our data have been used by others. Most of the results will make PhD for students and will make papers that will be published in scientific journals. The previous projects gave the following PhD thesis:

Christodoulou, A. (1986), Etude microsismique et évolution d'un graben complexe, exemple le graben mygdonien (Grèce du Nord).
Pedotti, G. (1988), Etude sismotectonique du Péloponnèse et Réponse sismique d'une vallée sédimentaire en Grèce du Nord.
Martin, C. (1988), Géométrie et cinématique de la subduction égéenne, structure en vitesse et atténuation sous le Péloponnèse.
Besnard, M., (1991), Simotectonique de L'Arc Egéen: résultats d'une campagne de microsismicité.
Amorèse, D., (1993), Sismotectonique et déformation actuelle de la terminaison nord-occidentale de l'Arc Egéen.
Rigo, A., (1994), Etude sismotectonique et Géodésique du Golfe de Corinthe (Grèce).
Lemeur, H., (1994), Tomographie tridimensionnelle à partir des temps des premières arrivées des ondes P et S, application à la région de Patras (Grèce).
Bouin, M-P., (1994), Analyse de la polarisation des ondes S en source proche: Rupture et Structure.
Kementzetzidou, D., (en préparation), Sismotectonique et risque sismique dans la région de Volos (Grèce).
Riepl, J., (en préparation), Propagation d'ondes dans un milieu hétérogène, application au risque sismique.
Le Brun, B., (en préparation), Diffraction des ondes sismiques par les hétérogénéités de surface.
Kassaras, I., (in preparation), Seismotectonics in westren Greece and Patras.
Diagourtas, D., (in preparation), Experimental study of the Empirical Green function method .
Ziazia, M., (in preparation), Seismotectonics of Central Greece and the Gulf of Corinth.

10) ONGOING PROJECTS AND PREVIOUS PROPOSALS

We have been funded by the European Community in the past by the Stimulation program (1986-1989), the EPOCH program (1992-1994) and the Environment program (1994-1995) to study seismic hazard in Greece. We studied in great details the seismicity and focal mechanisms in Thessaloniki, Peloponnese, western and central Greece, and the south Aegean sea. We conducted a detailed study of the tectonics and mechanism of the Gulf of Corinth (tectonics, geodesy, seismicity). We participated in the Euroseistest around Thessaloniki to better predict the ground motion during a strong earthquake.

Most of these projects were successful in the terms that they provided good and useful data which helped in improving significantly our knowledge of the tectonics and associated seismic hazard in Greece. They also helped in improving the methods (experimental and numerical) which are neccessary to identify the potentially dangerous regions and to compute the expected ground motion. These data are available and are used by the scientific community.

The results of these projects were published in scientific papers and presented in many scientific meetings. Several tens of students defended (or are going to defend) PhD thesis with data provided by these projects, some of the PhD are avised in common. We practiced visits of short and long period of thime. We have now a very good and efficient collaboration in gathering, processing data, and in scientific exchanges.

We are aware of different other projects that are submitted to the Environment and Climate program and are complementary of our proposal. One is devoted to study the physical parameters which could be validated as seismic precusors. Another is devoted to develop numerical methods to better model the data gathered around the Euroseistest of Thessaloniki. The third is devoted to develop avanced technologies related to space technics.

The other proposals are different, but complementary, of our proposal because seismic hazard needs a multidisciplinary approach. We know, and have collaborated in the past with people involved in the other proposals, so we think that we gather very efficiently our forces to reduce seismic hazard in this way.