THE CITY OF PATRAS-W.GREECE: A NATURAL SEISMOLOGICAL LABORATORY TO PERFORM SEISMIC SCENARIO PRACTICES

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1. Introduction

Greece is the most earthquake-prone country in Europe, with about 2% of the whole world's seismic energy release. This takes place within an area accounting for only 0.009% of the world's total area. The cost of repair and reconstruction after the earthquakes in the last decade in Greece is estimated to be around 700 million European Currency Units per year. The indirect cost of earthquakes, due to loss in GNP, social problems, etc., is even higher.

The city of Patras is the capital of Western Greece, the most seismically-active region in the country and Europe (cf. Strong Motion Earthquake Instrument Arrays, Proc. of the International Workshop, Honolulu 1988, W.D. Iwan, Editor, in which Patras was proposed for the deployment of a strong motion instrument array—along with 27 other locations worldwide—as the most suitable location in Europe).

Despite its relatively small size, the city of Patras has been considered as a second international site, after the city of Quito, to perform an earthquake scenario experiment. It is a common engineering practice to employ models in order to test theories or construction practices. Thus, it is much easier to construct a damage scenario of a relatively small city which shares all the interesting factors of an earthquake-prone megacity (variability in building construction, various geological regimes, high seismic risk, etc.), and then, after having tested all the required research tools and developed new methods for seismic hazard mitigation, to try to generalize their application to larger cities. The recent catastrophic earthquake makes Patras a favorable test city to develop and finetune seismic scenario practices.

2. Seismotectonic Regime

The seismicity of the region reflects the complex geodynamics of Greece, which are determined by the convergence of the African and European lithospheric plates [Figure 1]. Furthermore, the Patras seismotectonic region is even more complex since it lies at the junction of two different structural trends within the current neotectonic extensional regime of an approximately N-S direction. The first is the WNW-ESE zone of extension defined by the Gulf of Corinth graben; the second is the NE-SW faulting associated with the Rio graben which has been interpreted as a transfer (transtensional) fault zone linking the Gulf of Patras graben in the southwest with the Corinth-Trichonis zone of extension in the northwest [Figure 1].

B. E. Tucker et al. (eds.), Issues in Urban Earthquake Risk, 315–326.

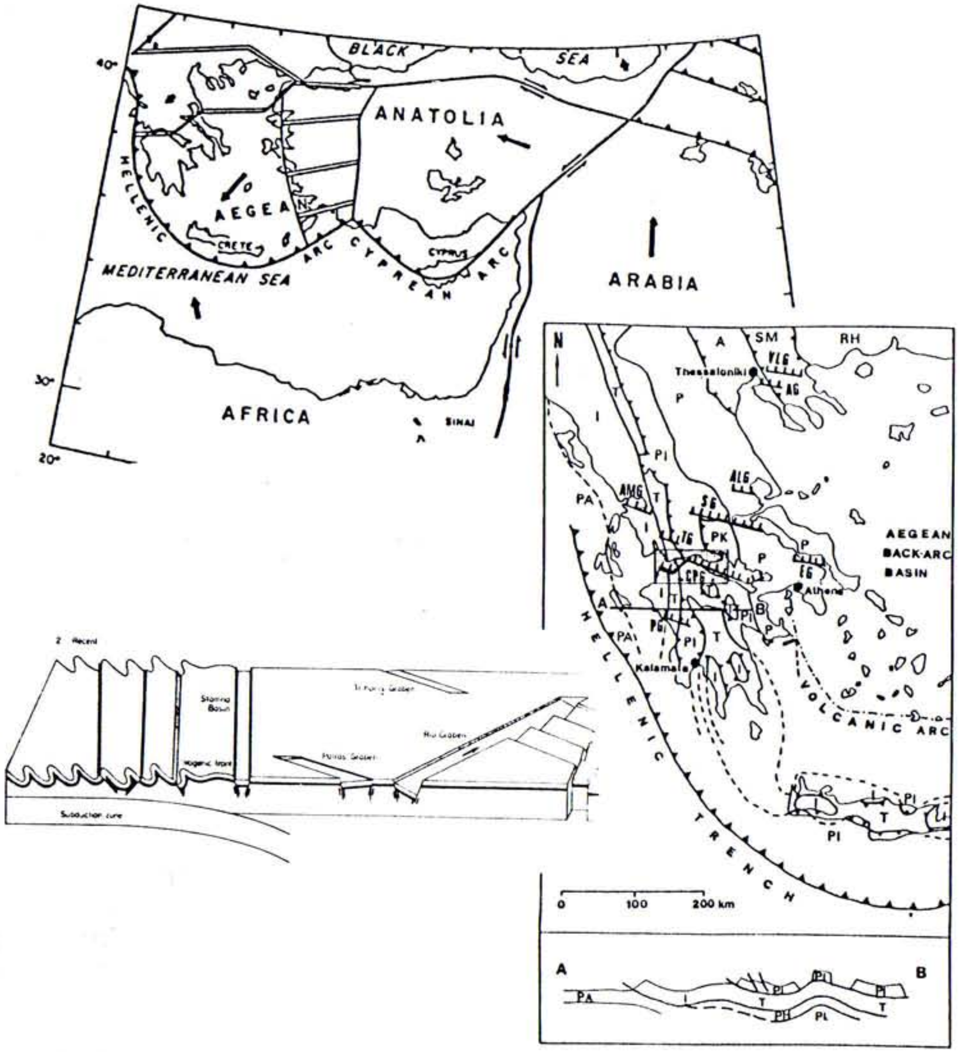


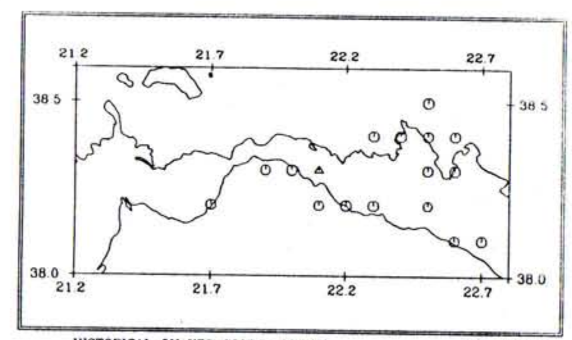
Figure 1. Seismotectonic Regime (modified from Doutsos et al. 1988)

2.1 HISTORICAL SEISMICITY IN THE PATRAS AREA

Macroearthquake catalogues and earthquake studies show that destructive earthquakes have occurred during historic times. The city of Patras has been destroyed many times in the past by earthquakes. Many of these earthquakes also triggered tsunami. The most famous event was that of 373 B.C. (with an estimated magnitude greater than 7.5 on the Richter scale), during which the ancient civilization of Helice totally disappeared. Even today one can observe in a nearby roadcut the face of the fault which was responsible for the aforementioned event. In Table1 we have collected from the existing literature all the available historical data while Figure 2 depicts the events with magnitude greater than 6.

(year	TIME date	hr	min)	LAT (°N)	LON (°E)	DEPTH (km)	MAG (Ms)
	BC						
600				38.3	22.6	s	6.8
373	WINTER	NIGHT		38.2	22.2	s	7.0
348				38.4	22.5	s	6.7
279				38.4	22.6	s	6.8
	AD						
23				38.3	22.0	s	6.5
551	JUL 7			38.4	22.4	s	7.2
996				38.3	22.4	s	6.8
1147				38.50	22.50	s	6.25
1402	JUNE			38.1	22.4	s	7.0
1580				38.4	22.3	s	6.7
1660	MAR			38.3	22.5	s	6.4
1714	JUL 27	6	0	38.2	21.7	s	6.6
1742	FEB 22			38.1	22.5	s	6.0
1748	MAY 27	15	0	38.2	22.2	s	6.8
1753	MAR 8			38.1	22.6	s	6.2
1785	JAN 31	4	0	38.2	21.7	s	6.6
1804	JUN 8	3	0	38.2	21.7	s	6.6
1806	JAN 23	-		38.3	21.9	s	6.3
1817	AUG 23	8	0	38.2	22.1	s	6.5
1861	DEC 26	6	30	38.2	22.3	s	6.7
1862	JAN 1			38.25	22.25	s	6.0
1870	AUG 1	-0	41	38.5	22.5	s	6.8
1876	AUG 6	11	0	38.25	21.75	s	4.70
1883	NOV 14	0	45	38.25	21.75	s	4.70
1885	FEB 18	14	30	38.50	21.75	s	5.8
1885	JUL 14	0	4	38.25	21.75	s	4.70
1887	OCT 3	22	53	38.1	22.6	s	6.3
1888	SEP 9	15	15	38.1	22.1	s	6.2
1889	AUG 25	19	13	38.3	20.1	61	7.0

s: shallow earthquakes (depth ≤ 60km)



HISTORICAL QUAKES 600BC-1900AD

21 Events
Scale 1: 140000

2.2 PRESENT SEISMICITY

Figure 3a presents the seismicity of Greece during the last century. The concentration of earthquake epicenters towards the west is characteristic. Even the short-term seismicity of the region depicts a similar pattern. Figure 3b shows the microearthquake activity in the region as it was evaluated by the region's recently-established microearthquake network of the University of Patras. A map showing the average intensities experienced in Western Greece during the present century is presented in Figure 3c.

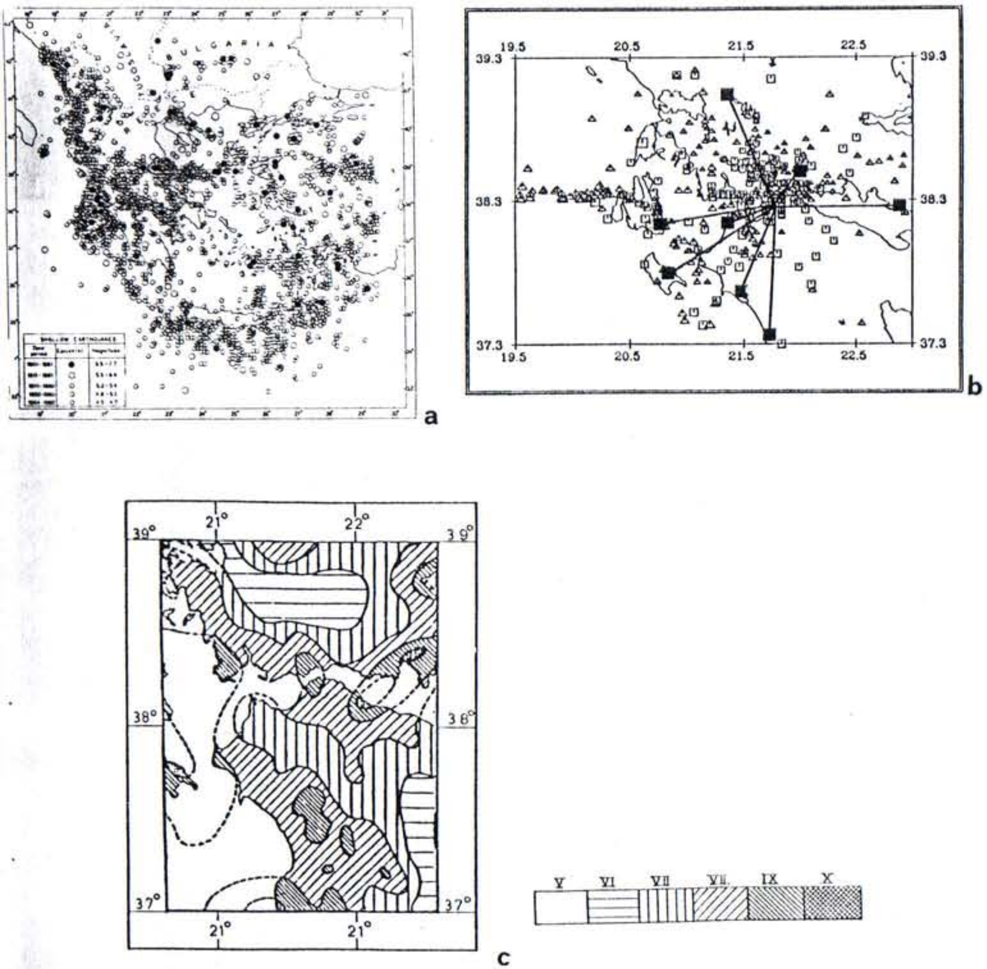


Figure 3:(a)Seismicity of the region during the the 19th century, (b)Short-term (4 months) seismicity, (c)Average intensities.

3. Geological Regime

The broader area of the city of Patras is emplaced in the gulf of Patras basin. The basement rocks, which outcrop in the mountainous area eastward to south-eastward of the city, consist mainly of flysch formations and of thin-bedded limestones and radiolarties. The plio-pleistocene sediments of the basin, exhibiting gentle morphology (elevation up to 200 m) and dipping to the south are mostly covered by old quaternary and recent alluvial deposits. Two horizons can be distinguished in these sediments, namely a lower fine-grained one with a thickness greater than 150 m, and an upper coarse-grained one usually of 50 m thickness.

In the narrow area of the city, which has a medium to low relief, the plio-pleistocene sediments developed consist of dark-grey marls, silty clays and sandy silts in the lower horizons, while in the upper ones alternations of clays, sands and gravels, conglomerates and clayey silts predominate. According to the data of the boreholes carried out, the total thickness of the plio-pleistocene sequence exceeds 300 m and in the coastal zone is covered by younger quaternary deposits.

There are parts of the city built on top of alluvial deposits and sands (region 1 in Figure 4a) with high liquefaction potential. There are also parts of the city built on top of hard rock (region 2 in Figure 4b), or on the top of low thickness sediments. Thus there exists a great variety of geological conditions, even interesting topographic surface and bedrock features.

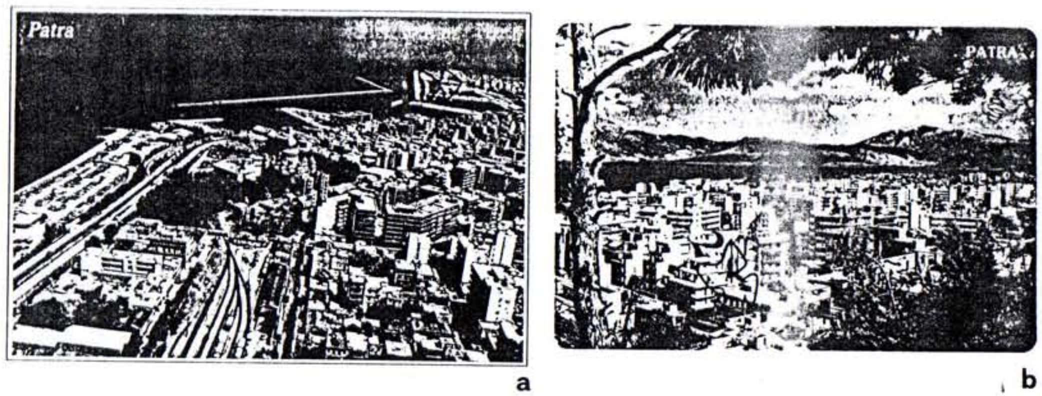


Figure 4:(a)NE view of the city, (b)SW view of the city.

3.1 ACTIVE FAULTS

Recent investigations by the Geology Department of Patras University have revealed the existence of about 500 active faults with length greater than 1.5 km in NW Peloponnesus (Figure 5a). As indicated by slickensides, the kinematic picture of the region is characterized by NNE trending movements along WNW trending faults. The total geological offset across the WNW trending faults near the earth surface was estimated by addition of the maximum thickness of the sedimentary prism, which was deposited in the hanging wall block of the fault, and the high of the fault scarp. Figure 5b gives total offset estimations for 41 major active faults of the region.

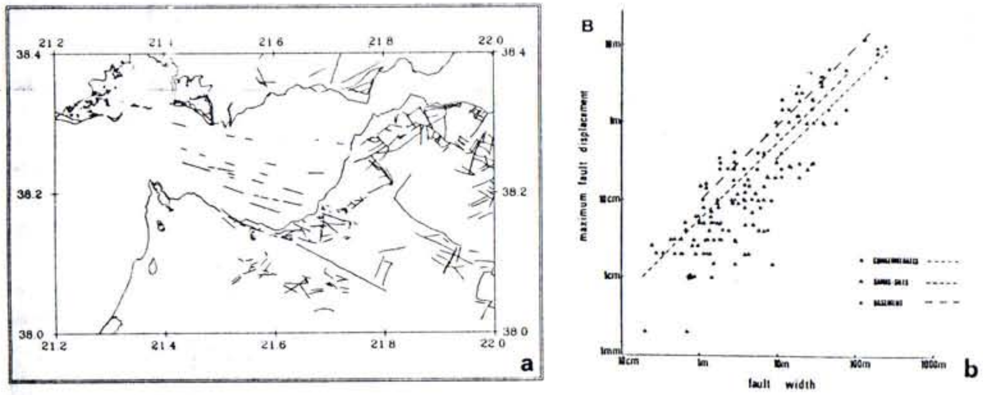


Figure 5:(a)Active faults in the region, (b)Offset estimations (from Doutsos and Poulimenos 1993).

3.2 AN ACTIVE FAULT THROUGH THE CITY

Patras is characterized by a unique geological phenomenon: an active fault runs through its most heavily populated part, resulting in considerable damage to buildings and lifelines.

Patras was struck on August 31, 1989 by an earthquake of small magnitude which caused serious damage to new multi-story and old two-story buildings in a limited area of the city. The main earthquake of magnitude 4.8 with a focal depth of about 3 km, occurred at an epicentral distance of about 5 km from Patras. This earthquake was followed by a series of shocks (Ms=4.5-5.2) in 1990, with epicenters located inside the Gulf of Patras and an epicentral distance from the city of less than 10 km. It is important to mention that the structural damage of buildings was observed in a narrow elongated zone, about 1500 m long and 50 m wide (Figure 6), along a surface rupture related to the reactivation of a normal fault which has been recognized in old airphotos (years 1945 and 1960). This normal fault has an observed length of more than 4 km, one of its edges being at the coast and the other at the mountains. It strikes N70E and is parallel to one of the main groups of faults affecting the plio-pleistocene deposits in the border area of Patras.

The main part of the rupture observed was extended in free ground, causing damage in road pavements and lifeline systems, whereas some part was extended to a heavily-populated area of the city of Patras and caused serious damage to many buildings. This damage was closely related with the surface rupture, whereas the discontinuity of the ground resulted in an unavoidable break in certain parts of the structures along the fault trace. It is obvious that this fault provides a unique opportunity to study seismic scenarios as related to active faults in cities.

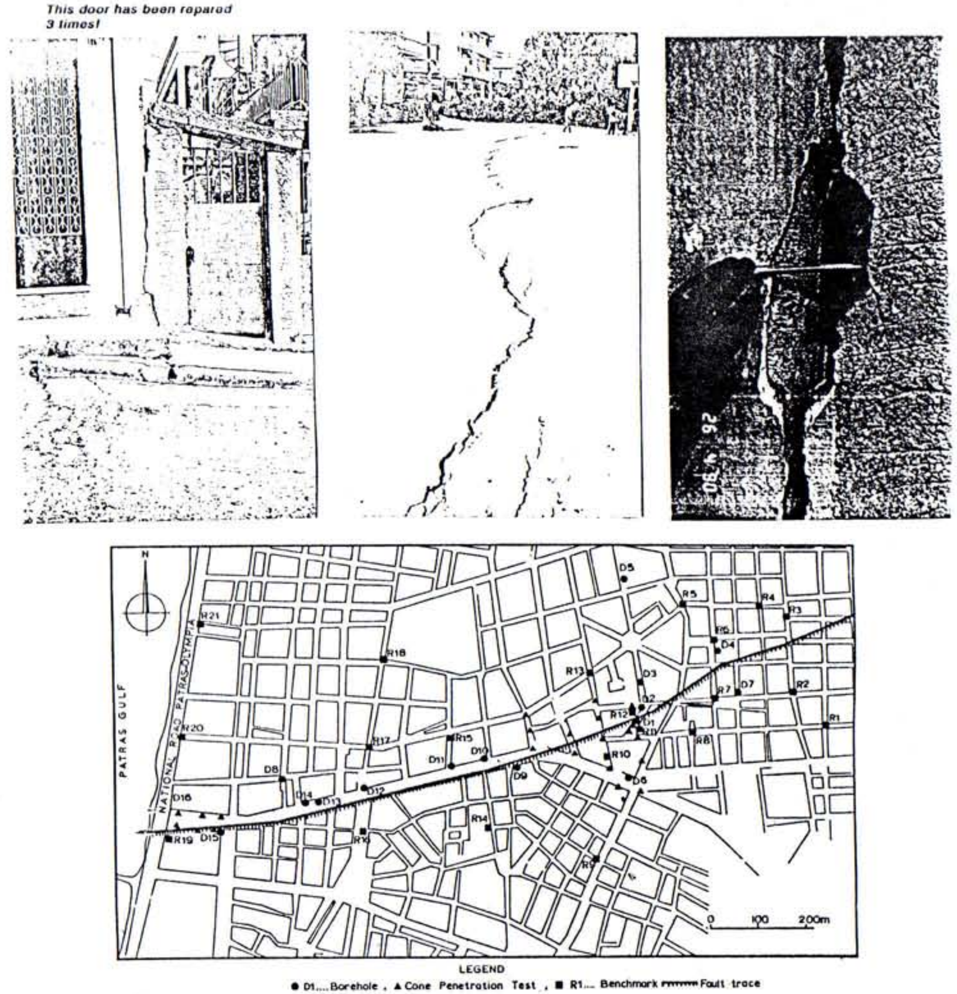


Figure 6: An active fault crosses the most heavily populated part of the city.

4. The July 14, 1993 Earthquake

Just after the decision to develop a seismic scenario in the city, a catastrophic earthquake occurred at the outskirts of the city. Despite its relatively small magnitude (Ms=5.5), it caused considerable damage to the city's buildings, particularly the old ones. Forty-five percent of the city's buildings were damaged, and 12% of them will be demolished. An increase in damages was observed in regions characterized by soft soils (coastal zone, old buried channels). The extremely high degree of damage experienced even by modern buildings in certain parts of the city highlights the importance of site effects.

5. Earthquake Awareness

5.1 SEISMOLOGICAL CENTER

The University of Patras has recently established in the region an eight-station radiolink microearthquake network (Figure 3b, Figure 7). Despite its relatively small time of operation, the analysis of the obtained data has resulted in the delineation of the major earthquake zones and the understanding of the seismotectonic regime.

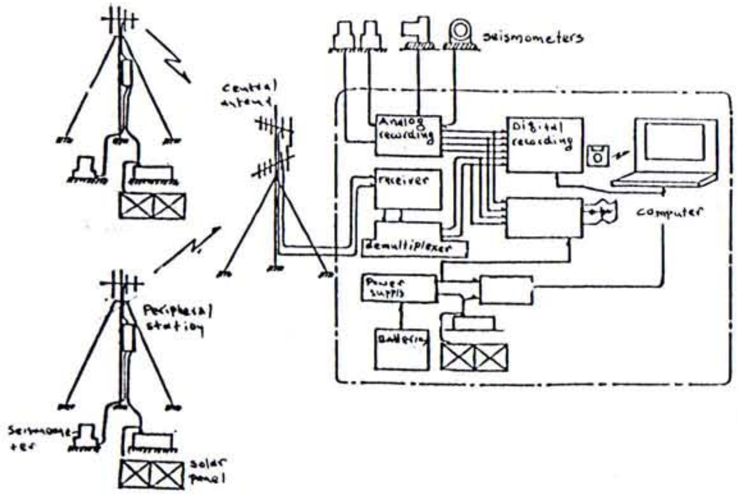


Figure 7: Organization of Patras microearthquake network.

When an earthquake of considerable size occurs, the seismological center informs the local authorities of the spatial and temporal evolution of the aftershock sequence, assessing throughout an algorithm of the probability of occurrence of a greater event or a major aftershock.

In addition to routine seismological monitoring, an earthquake prognostics laboratory has been established for the investigation of earthquake precursors. The prediction strategy is to continuously monitor as many physical parameters as possible (Figure 8), compare the results with the seismic activity, build up a model valid for explaining the phenomena, and provide information on future research activities (Figure 8). In certain cases, where there are serious indications of the existence of precursor signals, the local authorities are informed.

The fact that the Earthquake Prognostics Center operates within a region which is characterized by extremely high seismicity makes it a natural earthquake prediction laboratory, where various research teams from many countries have expressed their interest to perform experiments.

PRECURSOR MONITORING		No of stations
(a)	Microerthquake activity[c]	6
(b)	Variation of b-value[c]	
(c)	Variation of r-value[c] (Patterns of earthquake sequences)	
(d)	Variation of Q[c]	
(e)	Sea tide observation[c]	2
(f)	Underground water (level,temperature)[u]	2
(g)	SES monitoring using the VAN method[c]	3
(h)	Long period electric anomalies[c]	3
(i)	Resistivity changes[c]	1
(j)	Global Positioning System (GPS)[p]	6
(k)	Electromagnetic observations at 10 and 81 KHz[u]	2
(l)	Low (20-60Hz) and high (>300Hz) geosound monitoring[u]	2
(m)	Radon gas observation[p]	1
(n)	Velocity anomalies[u]	6
(o)	S-wave Polarization[u]	

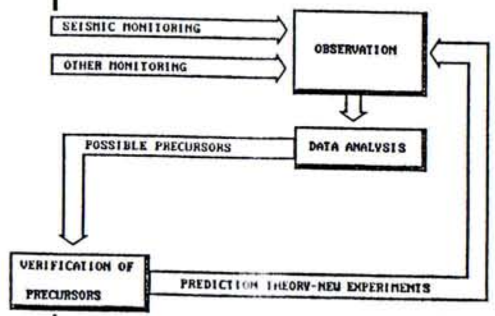


Fig.8: Earthquake Prognostics Strategy C=combleted, U=under development P=planed.

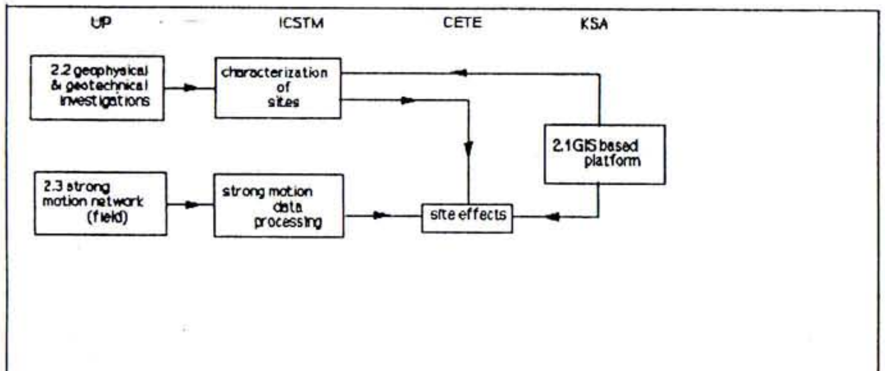
5.2 SEISMIC SCENARIO

The Municipality of Patras has realized the high seismic risk of the city and has recently decided to support the development of its seismic scenario.

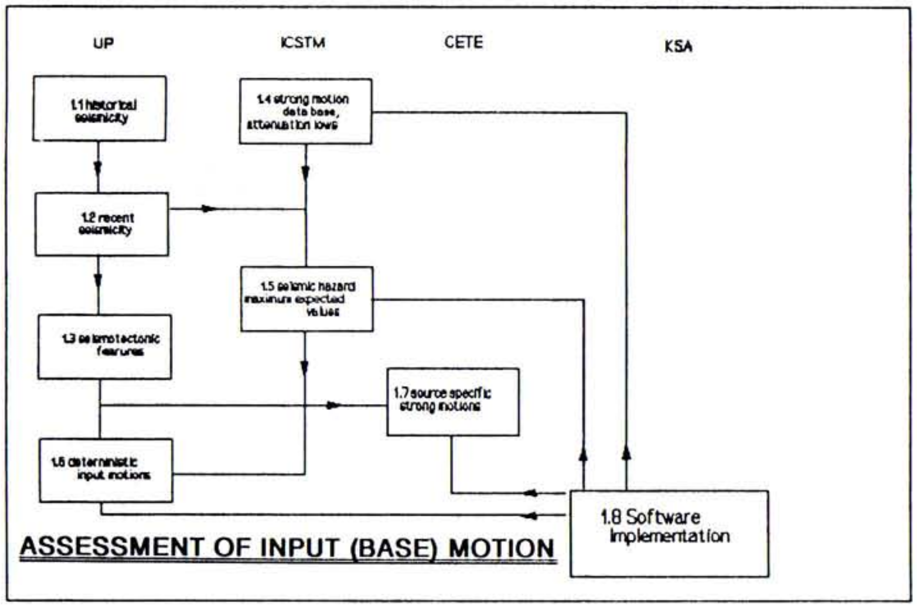
This will be a pilot project partially financed by the Municipality of Patras, the Chamber of Civil Engineers and GeoHazards International. A later stage of the project, which has been submitted for approval to the European Community, deals with the generalization of the project's results to other Mediterranean cities. Figure 9 depicts in detail the various stages of the work, which is planned to start in early 1994 and is expected to last two years.

The recent catastrophic earthquake of July 14, 1993 which caused serious damage to the city's buildings, provides us with a unique chance to judge the scenario's results and finetune the methodologies developed.

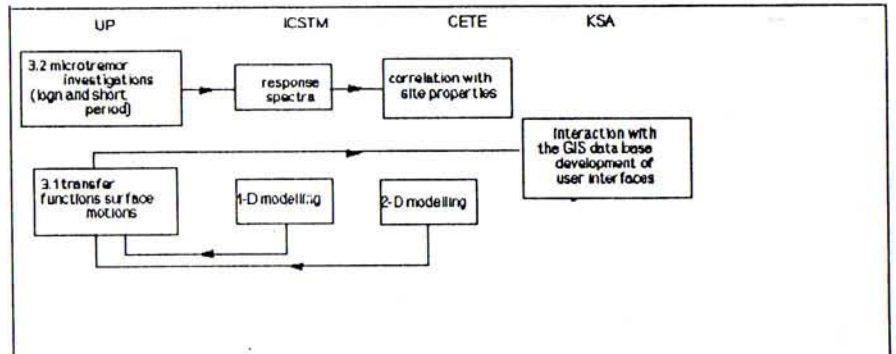
After the completion of the project, the obtained results will be integrated into the city's Geographic Information System and will be disseminated to all interested parties. For example, civil engineers will have the opportunity to link via modem to the main database and obtain information about the response spectra at each construction site, the local authorities will be able to perform earthquake exercises triggering various earthquake scenarios, etc.



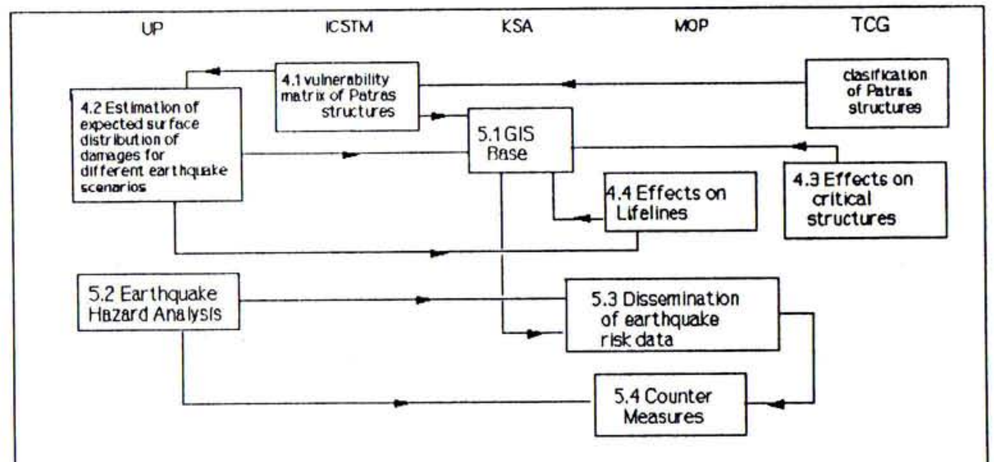
CHARACTERIZATION OF SITES



ASSESSMENT OF INPUT (BASE) MOTION



ASSESSMENT OF SURFACE GROUND MOTION



ASSESSMENT OF STRUCTURAL DAMAGE
END USER APPLICATIONS

References

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