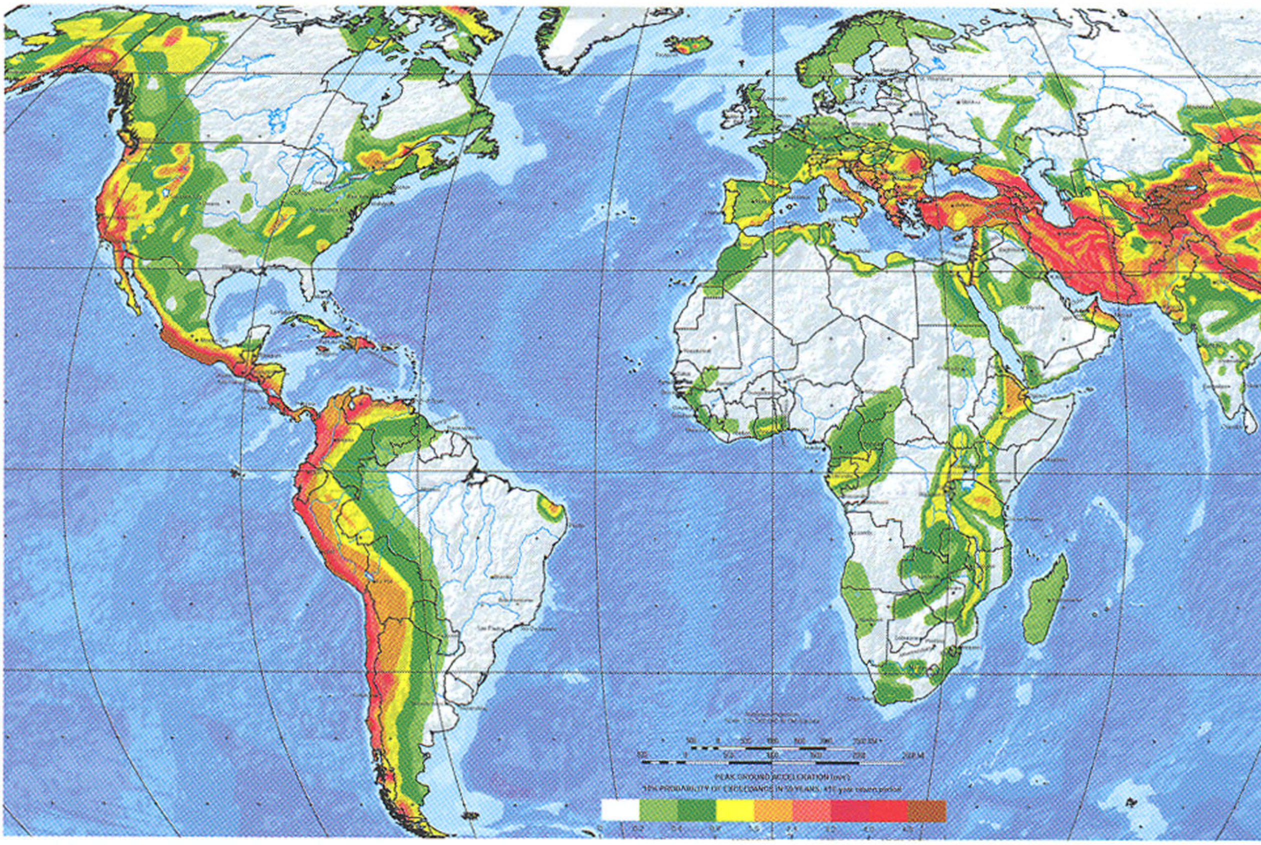

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A MULTIDISCIPLINARY PROJECT FOR URBAN AND EMERGENCY PLANNING IN SEISMIC REGIONS: THE CASE OF PYRGOS CITY (W. PELOPONNESE GREECE)

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ABSTRACT

Pyrgos city (W. Greece) is characterized by high seismicity, due to its neighboring to the convergent boundary between the Eurasian and the African tectonic Plates. On March 26, 1993, the city was hit by a Ms=5.5 earthquake that inflicted significant damages. The impact of the event was studied through a multidisciplinary project that included: (i) geological investigation and detailed geological mapping, (ii) neotectonic mapping, determination of faulting parameters and localization of the active tectonic structures, (iii) seismicity and seismic hazard investigation, (iv) geotechnical investigation, including a series of exploratory drillings and soil tests, (v) examination of the building vulnerability within the urban complex, and (vi) urban development study that focused on parameters pertaining to earthquake hazard. The project resulted in the compilation of an emergency operation plan which included segmentation of the town into distinct sectors, escape and aid routes, first aid stations and refuge camps.

Introduction

Potential damage after natural phenomena is largely increased in Greece during the last few decades due to the quick development of the cities. In urban environments with adverse seismotectonic and geodynamic framework seismic risk is further increased. Not only large magnitude earthquakes, but also small magnitude, focal depth and epicentral distance earthquakes can be catastrophic. Some recent typical examples of the latter kind of earthquakes in Greece occurred at Killini (1998), Milos (1992), Pyrgos (1993) Grevena and Egio (1995) and Athens (1999).

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Earthquake risk management in modern cities requires a series of studies and administration proceedings (Fig. 1) which are divided into three stages namely: Stage A: Protection (Organization Framework), Stage B: Emergency action and Stage C: Confrontation (Restoration).

In Stage A the consequences of a potential earthquake can be minimized through appropriate organization plans which include determination of the potential risk and allocation of the financial resources required. Stage B involves reaction and intervention aiming in minimization of human casualties. Stage C refers to the promptest and fullest restoration of the social, administrative and financial function of the city. The ultimate goal is restoration to the conditions prior to the earthquake but with safer conditions.

Geology and Seismicity

Pyrgos graben is an Alpine tectonic structure (Triassic to Oligocene) that was subsequently filled by younger, post alpine sediments. The Alpine basement is 2,500-3,000 m below surface. The fault zones that border Pyrgos graben have been reactivated many times from Miocene to Holocene reaching total throw of a few kilometers (Lekkas et al., 1992 and Mariolakos et al., 1995). The following geologic formations cover the region (Fig. 2):

- Marsh Deposits. Alternations of brown to gray clay, gray to blue clayey silt and silty sand. There are plant remains within any soil type of this formation and its total thickness is approximately 5 m.
- Alluvium. Soft, brown to gray, clay with brown silt and brown gray sand intercalations. Plant remains and granular materials are frequent. The formation is less than 12 m thick, highly inhomogenous and anisotropic.
- Erimanthos Formation. Polimictic, terrigenous conglomerate with red silicaceous matrix of Pleistocene age. It overlays the palaeorelief and is 2-8 m thick.
- Vounargos Formation. Clay, silt, sand, sandstone and marl alternating continuously both in lateral and vertical sense. Two members are identified within this formation namely Agios Athanasios and Agios Nikolaos.

Faults crossing Pyrgos city are normal, sub-vertical, oriented east – west with throw more than 20 m. Some seismic fractures were generated on existing faults during the 1993 earthquake. Based on geotechnical and seismic data (spectral acceleration ratios at exploratory borehole locations) Bouckovalas (1994) determined that damage susceptible areas have more than 10 m thick recent soil deposits.

The earthquake at Pyrgos city had surface magnitude Ms=5.5, focal depth 20 km, and occurred on March 26, 1993 after a long foreshock period. At least 50% of the constructions were damaged and the calculated direct cost of the damage was approximately 160 million US$. Focal depth of aftershocks varied between 10-30 km. The rupture zone was found 10 km long and the average displacement measured on the fault plane was 17 cm. Seismic acceleration was large (0,45g), but it can be explained by the large displacement observed. The difference between the stress involved minus the relieved stress (5 bars) explains the intense sequence of aftershocks (Stavrakakis, 1994).

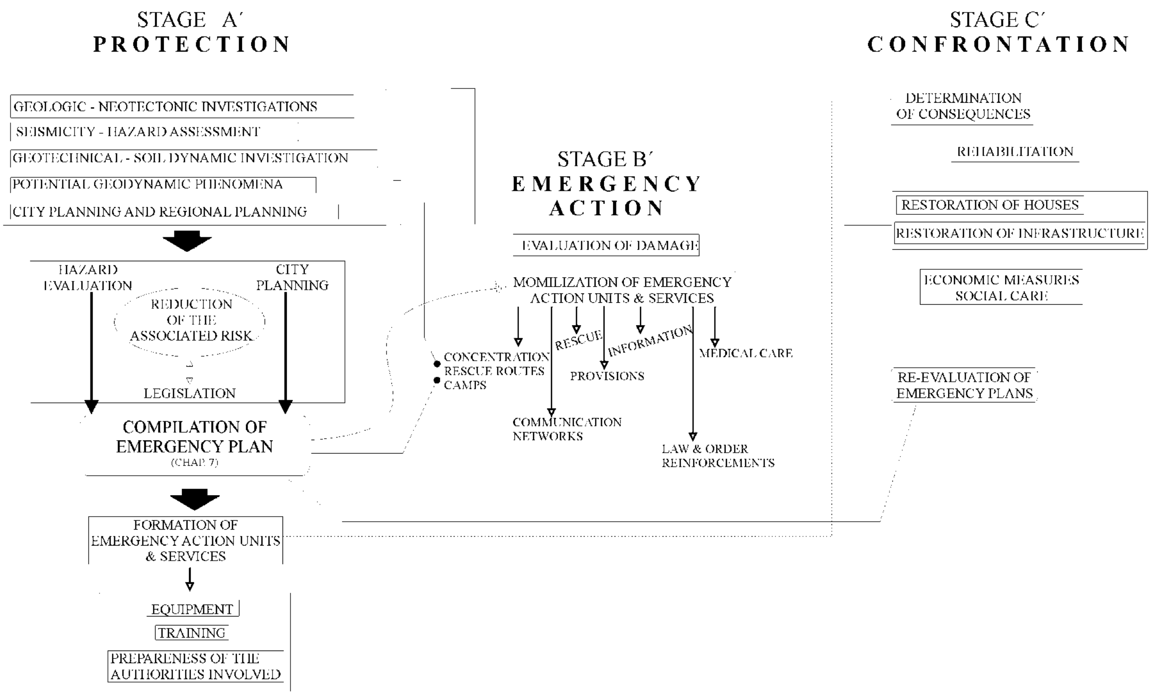

Figure 1. Flow chart of a three stage organization plan against seismic risk.

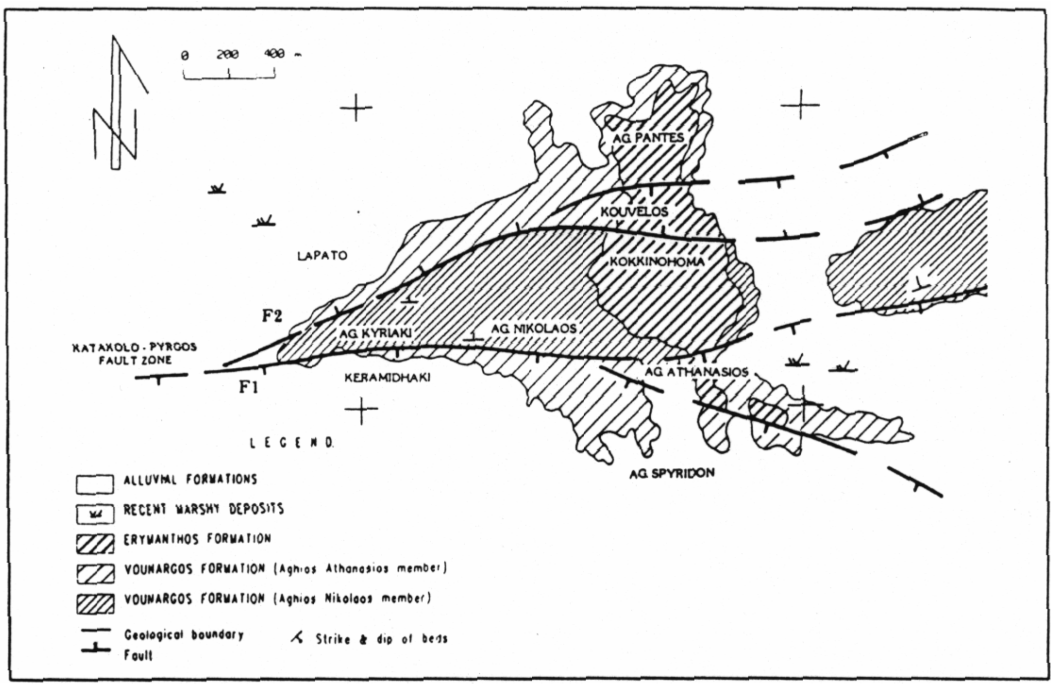

Figure 2. Geological map of the area of Pyrgos city.

Statistical analysis of seismicity showed that earthquakes 10 km, 40 km and 100 km away from Pyrgos city have maximum expected magnitudes are 6.5, 7.5 and 8.0 respectively (Stavrakakis, 1994). The return period of 50 years corresponds to a 4.8 to 5.3 magnitude earthquake, while 100 years return period corresponds to a 5.1 to 5.6 magnitude earthquakes.

Apart from seismic fractures, the 1993 earthquake also triggered overtoppling of sandstone blocks and caused soil liquefaction. Overtoppling occurred along the morphology discontinuity of an active fault zone (Vounargos Zone) without causing any damages. Liquefaction together with subsidence was observed at the coastal area (5 km^2) and at Alfios river banks. Damages where limited because the affected area was not heavily built. However, some sites within Pyrgos city, sitting on Alluvium and having high water table suffered from differential settlement due to subsidence, which was one of the most important damage controlling factors. The damage intensity map was carried out according to the European Macroseismic Scale – E.M.S. 1992 (Grunthal, 1993 & Lekkas, 1996) and shows that maximum intensity VIII was observed at the city center, while minimum damage (V) was observed south and northwest.

Urban Development - Emergency Planning

Vulnerability of the buildings is highly variable due to dissimilar building types and buildings of different age that tend to blend together in the neighborhoods (Fig. 3). To evaluate accessibility (defined as the ease of access to a particular point after a disastrous earthquake.) several weighted parameters such as road width, height of adjacent buildings, geometry of roads (curves, dead ends), one or two-way streets, must be taken into account. Weighted parameters combined with building vulnerability give a first estimate of accessibility. Figure 4 illustrates in three classes (bad, intermediate, good), the accessibility of Pyrgos city after a disastrous earthquake (design earthquake).

City zoning is necessary for the implementation of the emergency plans by the local and central authorities. Each of the 7 major sections of the city (Fig. 5) is further divided into 4 smaller sections. It was attempted to identify sections with similar area, building density, vulnerability and commons. Sub sections were established to facilitate operation management.

Actions following the event require a well-structured emergency plan that respects special local conditions and site specific characteristics. Unforeseen conditions are not desirable but if they arise, they should be resolved as soon as possible and not postponed. The actions that had to be taken immediately after the earthquake (emergency action) are the following:

- Evaluation of the extend of damage.
- Implementation of evacuation, assembly and first aid plans.
- Extinguishing fires.
- Rescue and transportation to hospitals.
- Hospitalization - burial of dead.
- Opening of roads (removal of obstacles and demolition).
- Provisions (food, water and clothing).
- Surveillance of constructions.

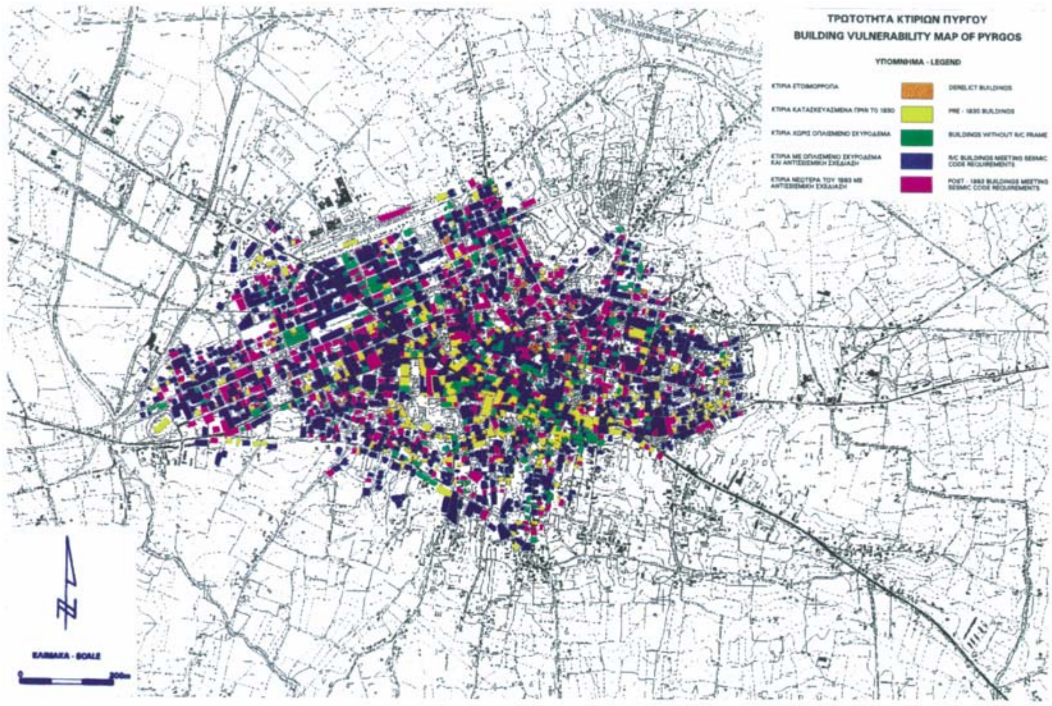

Figure 3. Building vulnerability map.

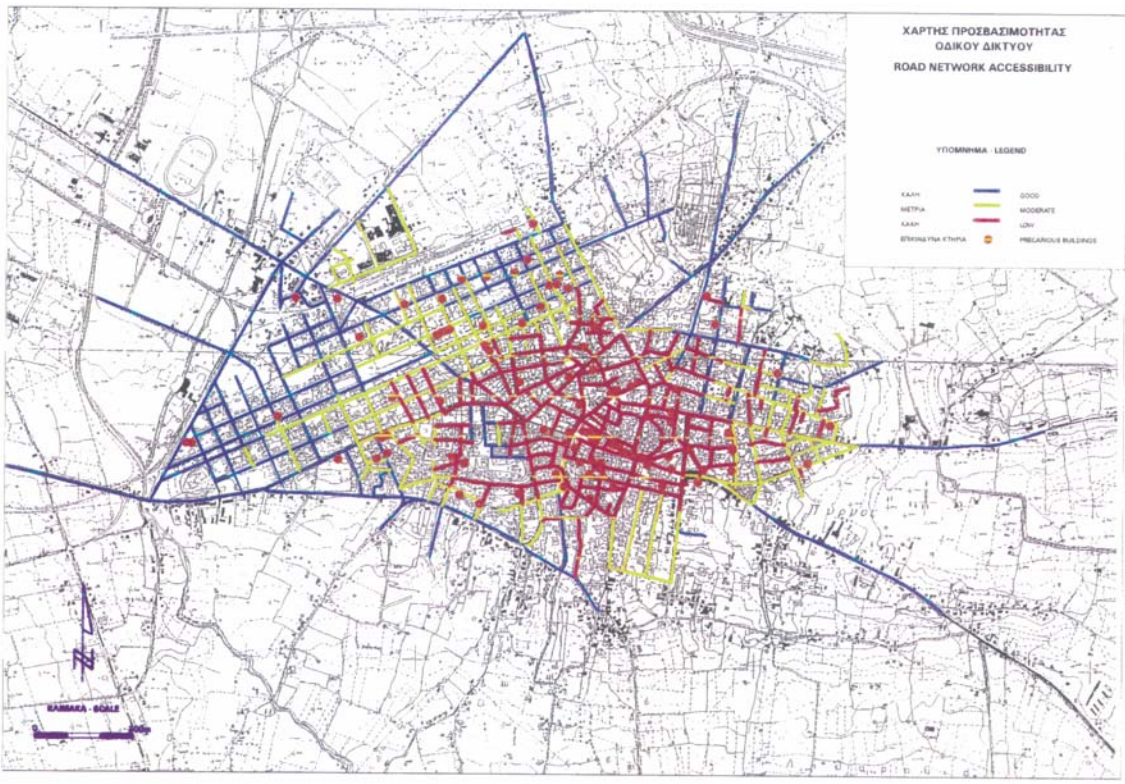

Figure 4. Accessibility of the road network.

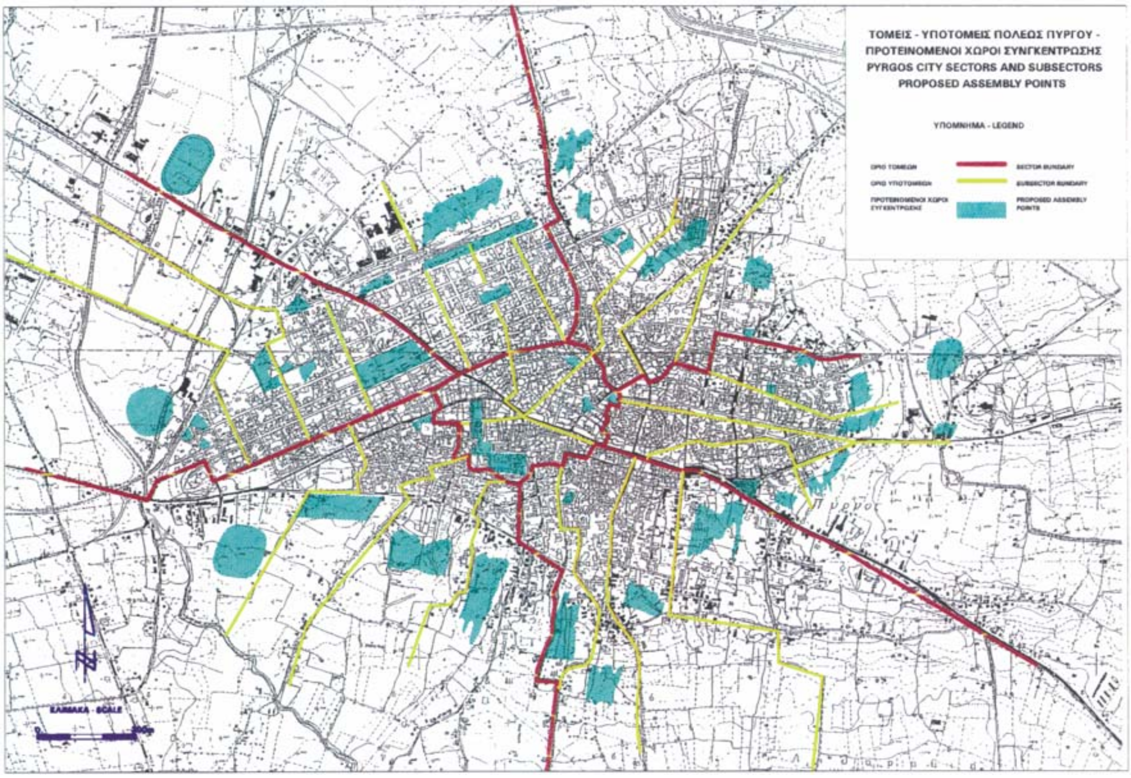

Figure 5. City sectors and proposed assembly points.

Emergency operation involves a great number of authorities, service organizations, units assigned special duties and requires special technical support. Success of an emergency action plan is directly proportional to the preparedness of personnel and availability of equipment. Continuous training programs and frequent inspection of equipment are therefore necessary. A data base which will include spatial information (Geographical Information Systems - G.I.S.), before the disaster can facilitate emergency action and decision making, by modeling probable disaster scenarios.

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