



**EARTHQUAKE ENGINEERING
RESEARCH INSTITUTE**

NEWSLETTER

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News of the Profession

Tobin Leaving CSSC

L. Thomas Tobin has announced that he will be resigning his position as Executive Director of California's Seismic Safety Commission effective July 31, 1995. During his ten years of leadership, the Commission created the California Earthquake Hazards Reduction Program and wrote *California at Risk*. It led the way in getting numerous pieces of legislation passed and programs instituted, including the Unreinforced Masonry Building Law, Proposition 122, the Seismic Hazards Mapping Act, hospital retrofit requirements for the Alquist Hospital Seismic Safety Act, the Essential Services Buildings Act, the Private Schools Act, Home Owner's and Commercial Property Owner's Guides programs, and requirements for mobile home installation tie-downs.

Learning From Earthquakes

Quakes Hit Greece, Philippines, Indonesia, United States

A magnitude 6.6 earthquake hit central Greece at noon on May 13, 1995. The region is considered to be among the least seismically active areas in Greece. Nearly 1,000 houses collapsed. An additional 10,000 buildings were damaged to the point of being unusable. Nevertheless, no deaths have been reported. Professor Panayotis G. Carydis of the National Technical University and several of his colleagues arrived at the stricken site within a few hours of the main shock. Their reconnaissance report is included as an insert in this issue of the newsletter.

EERI member Vincent Porrazzo forwarded some additional information about the series of five earthquakes that hit the Philippines on April 20-21, 1995 (see May 1995 newsletter for preliminary report). The largest of the quakes was recorded by the Philippine Institute of Volcanology and Seismology as a magnitude 6.9. The quakes are apparently related to activity in the Philippine Trench, east of Mindanao. Damage to a steel multi-span arch bridge and a school was reported. Porrazzo noted that he and his colleagues felt one of the events in their five-story office building in Manila, 600 km from the epicenter. The building is situated in an area of deep, soft soil; very few people in other parts of Manila felt the motion.

On May 14, an earthquake-generated tsunami left one person dead and 16 missing along the coast of East Timor, Indonesia. An additional 22 people were reported injured. In the East Timor capital of Dili, the quake itself was strongly felt, but no damage was reported.

A light earthquake, magnitude 4.1, occurred in Montana on May 2, 1995. The quake was felt in the Kalispell area, but no damage was reported. On May 7, a magnitude 5.0 event occurred east-northeast of Palm Springs, California. The earthquake was felt in the Coachella Valley, and lightly felt in the Los Angeles area. No damage was reported.

The Commission's work after the Loma Prieta earthquake resulted in meaningful improvements to the earthquake programs at Caltrans, CSU, and the Department of General Services.

Tom is leaving the Commission to pursue long-delayed plans to re-enter the private sector to work with local governments and private companies in their efforts to cope with earthquakes and other hazards. EERI wishes Tom well in his new endeavors.

Travel Info for 5ICSZ, Nice, France

EERI is using the *Scan the World* travel agency (800-775-0200, Maria) for travel to the Fifth International Conference on Seismic Zonation, being held Oct. 17-19 in Nice, France. Limited travel grants are available. Applications are due by June 30. (See the May newsletter.) Information on air fares and hotel accommodation will be published in the July newsletter.

The Grevena (Central-North) Greece Earthquake Series of May 13, 1995

Pan. G. Carydis, Professor of Earthquake Engineering, NTUA; Konst. S. Holeva, Civil Engineer, Emergency Response Department, EPPO; Eft. C. Lekkas, Geologist, Assistant Professor, Athens University; and Tax. D. Papadopoulos, Geophysicist, Assistant Professor, Athens University, are members of the scientific emergency committee advising the interministerial coordinating board of Greece. The authors visited the earthquake-stricken area a few hours after the main shock and stayed on site for two days. The mission was initiated and supported by the Earthquake Planning and Protection Organization (EPPO).

Introduction

At 11:47 a.m. local time on Saturday May 13, 1995, a strong shallow earthquake of magnitude 6.6 on the Richter scale shook the Kozani farm area of central-north Greece. The earthquake was registered at 40.1° N latitude, and 21.7° E longitude, 130 km west of Salonika. The event was preceded by two minor foreshocks. This report refers to the findings and information up to the second day after the main shock occurred, unless otherwise mentioned. The report was written on May 18, the fifth day after the main shock.

No deaths were reported as a result of the earthquake. Fifteen injuries were attributed to the earthquake. Two rather severe incidents were due to road accidents. Seven hundred buildings totally collapsed in twelve villages of Grevena Prefecture and 200 in five villages of Kozani Prefecture. The number of uninhabitable houses increased dramatically day by day. From 2,000 such houses reported



Figure 1—Typical damage to the buildings in the region struck by the earthquake.

on May 14, the number reached 7,000 on May 17. Many strong aftershocks have been recorded within the range of 4.5 to 5.4 on the Richter scale while thousands of more minor earthquakes have

shaken the region almost continuously. The direct loss from the earthquakes is currently estimated at \$40 million U.S. dollars.

The affected area has an elliptical



Figure 2—The remains of the school in the village of Kendron.

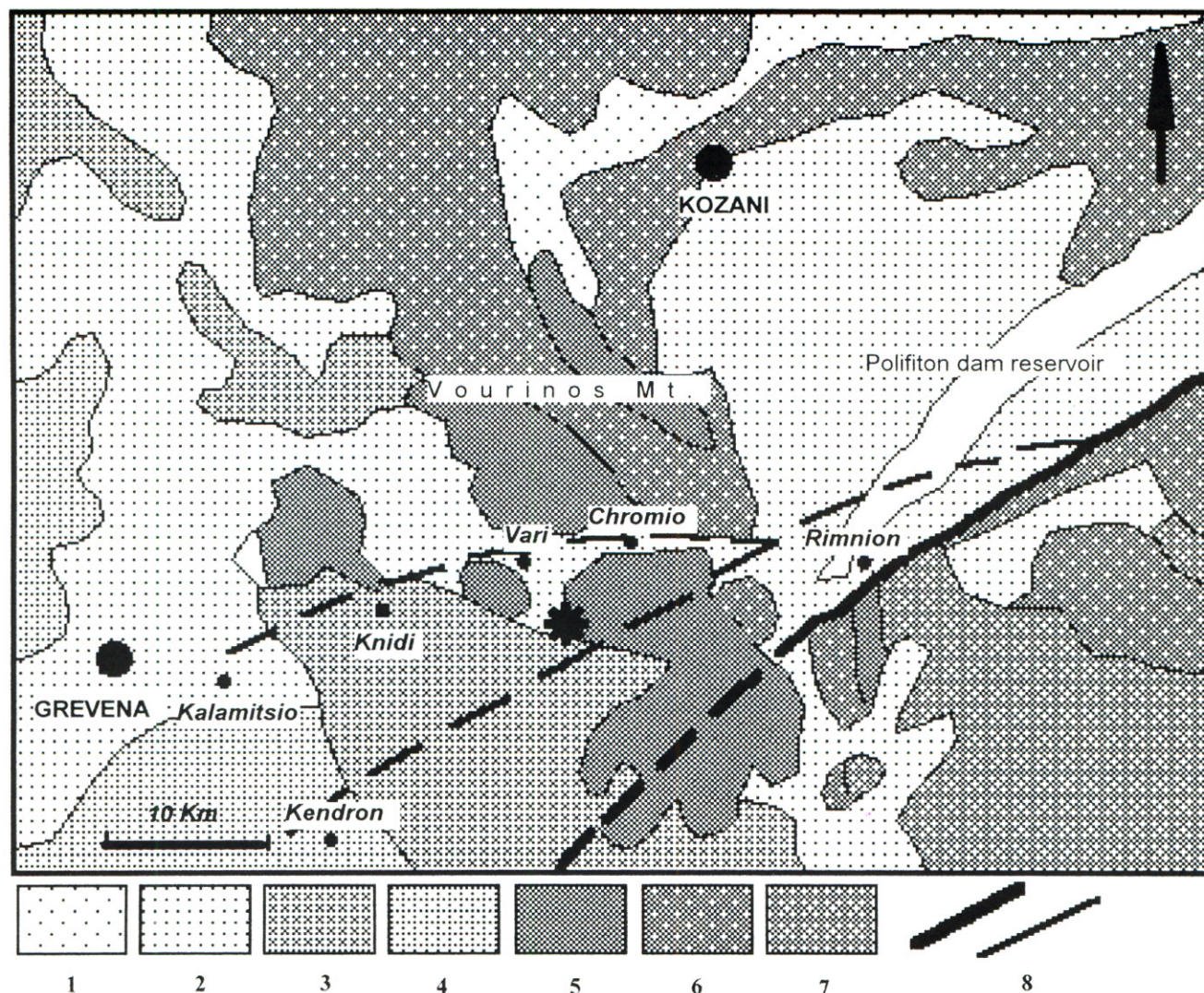


Figure 3—Simplified geologic map of the earthquake-stricken area.

shape covering 350 km². This area contains 80 villages. Among the uninhabitable buildings were 30 schools, 15 churches, and 2 hospitals. Power was unavailable for 30 minutes after the earthquake over an extensive part of the country.

Seismic History

The affected area lies in a region of low seismicity. There are two other such regions in Greece, Cyclades and Massif of Rhodope, which are the most stable ones. The nearest and largest earthquake reported since 1700 was an event which occurred on October 25, 1984. This earthquake, a magnitude 5.5 on the Richter

1. Alluvium - scree
 2. Plio-Pleistocene sediments
- MOLASIC SEDIMENTS**
3. "Tsotilion" formation
 4. "Pentalofon" formation
- ALPINE UNITS**
5. Ophiolitic complex
 6. "Eastern Greece" Geotectonic Unit Limestone
 7. "Flambouron" Geotectonic Unit Gneisse and Amphibolite
8. Fault zones and faults

scale, affected the village of Kranidia, 10-15 km northeast of the village of Rimnion. Rimnion was badly damaged by the recent earthquake. Two other previous

events were also recorded north of the currently damaged region. One was a Richter magnitude 4.7 earthquake at the city of Kozani on February 9, 1984.



Figure 4—Typical old house of the region reinforced with wooden beams. Houses of the same type but without the wooden beams suffered much more damage or collapsed.

The other was a Richter magnitude 4.8 on October 25, 1984, at the city of Ptolemais (data from the Geodynamic Institute of National Observatory of Athens). According to seismological reports the return period of the recent main shock is on the order of 1,000 years.

Geotectonic Structure

The affected region extends from the northwest boundary of the Messohellenic Trench, passes through Vourino ophiolites, Eastern Greece Unit limestone and dolomite, and reaches the south part of Kozani post-Alpine basis.

The tectonic structure is composed of a part of the eastern margin of the Messohellenic Trench, Vourinos Mt., and the Kozani Basin. Farther towards the east, a tectonic zone juxtaposes Vourinos Mt. and Kozani Basin which in turn is bordered on the south by the Servia fault zone of a NE-SW direction changing to E-W at Rimnion. No seismic rupture of the surface was observed after the main shock. However, a limited

number of rock falls, landslides, and some subsidence were observed.

Earthquake Motion

From the observations of people who were interviewed by the authors, the vertical component of

the ground motion was the most damaging. The order of magnitude of the vertical component after the interpretation of the evidence was estimated to be as high as 1 g. The authors also experienced many strong aftershocks during their stay at the meioseismic area. All of the aftershocks had strong vertical components of short duration and high frequency.

The duration of the main shock, as felt by the nearby people, coincides with the recorded data at the city of Kozani by IESEE. According to this record, the peak ground accelerations were: longitudinal: 0.21 g; transverse: 0.15 g; and vertical: 0.08 g. The duration of the strong phase was seven seconds, while that of the whole motion was 20 seconds.

Damage to the Built Environment

The general quality of the houses and other buildings in the region is poor. A large percentage of the collapsed buildings were old and not well maintained. Some buildings which were not properly built



Figure 5—The damaged church in the village of Knidi. The cracks are typical of the strong vertical component of the ground motion.

to earthquake standards suffered extensive damage.

The area under consideration is classified as the first and lowest seismic zone which, according to the new regulation for the earthquake-resistant design of structures, uses $a_0 = 0.12g$ compared with the fourth and highest seismic zone of Greece with $a_0 = 0.36g$.

Some of the non-engineered buildings in the region are adobe or rubble masonry with wooden reinforcing beams. This older type of building sustained the earthquake without suffering extensive damage. Most of the collapses were observed in one- or two-story rubble masonry houses built mainly without mortar. A considerable portion of these houses had been renovated using concrete and heavy tile roofs which were incompatible with the older building.

Additions and extensions to existing buildings resulted in an increase in the level of damage. The damage observed presented a rather symmetrical distribution about the vertical axes of the buildings. For example, the tiles were scattered from the top and center towards the lower edges. Characteristically, damage was observed at the corners of the buildings and roofs. The dominating damage patterns included horizontal and vertical cracking of walls, and dislocation of rigid members, such as lintels, from the structures. There was no crushing of joints observed between the ground floor and upper part of the houses.

Modern structures, built according to the seismic code, performed satisfactorily and sustained only minor damage, although designed for lower seismic loads. Some villages, although located inside the



Figure 6—A view of a damaged church in the village of Kendron.

meisoseismal region, suffered quite limited damage compared with neighboring villages that almost totally collapsed.

The fact that there were no deaths and few injuries is partially attributed to the occurrence of the two foreshocks. Due to the previous absence of strong seismic activity in the region, people were frightened immediately after the first foreshocks and evacuated their houses. The time lapse between the last foreshock and the main shock was short enough to keep people away from their houses. The earthquake also occurred on a Saturday, when both schools and churches were empty.

Lifelines

Traffic was interrupted on one bridge due to settlement of the fill

material of the embankments of the bridge approach roads. In 28 villages the power supply was interrupted. Within 24 hours all connections had been restored, except for eight villages and some minor housing units where building damage was too extensive. A similar condition is reported for the telecommunications systems. In most of the severely damaged villages the water supply was also interrupted.

Conclusions

This earthquake proved that the hypothesis of the existence of aseismic regions in an earthquake-prone country, of the size of Greece, must be abandoned.

Lessons learned from strong earthquakes in various territories in Greece have shown that the existing four seismic zones should be reconsidered for a better level of building safety.

The belief that the vertical earthquake motion is a rare phenomenon must be abandoned. The design and construction of structures to withstand this direction of motion must be reflected in the codes with the same reliability as for horizontal seismic motions.

The occurrence of foreshocks of an appropriate magnitude and time before the main shock gave people enough warning to leave their houses, and thus saved their lives.

The authors want to thank EPPO for initiating and supporting this mission, and Ms. Alice Moncaster for her assistance with the wording of the manuscript.

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