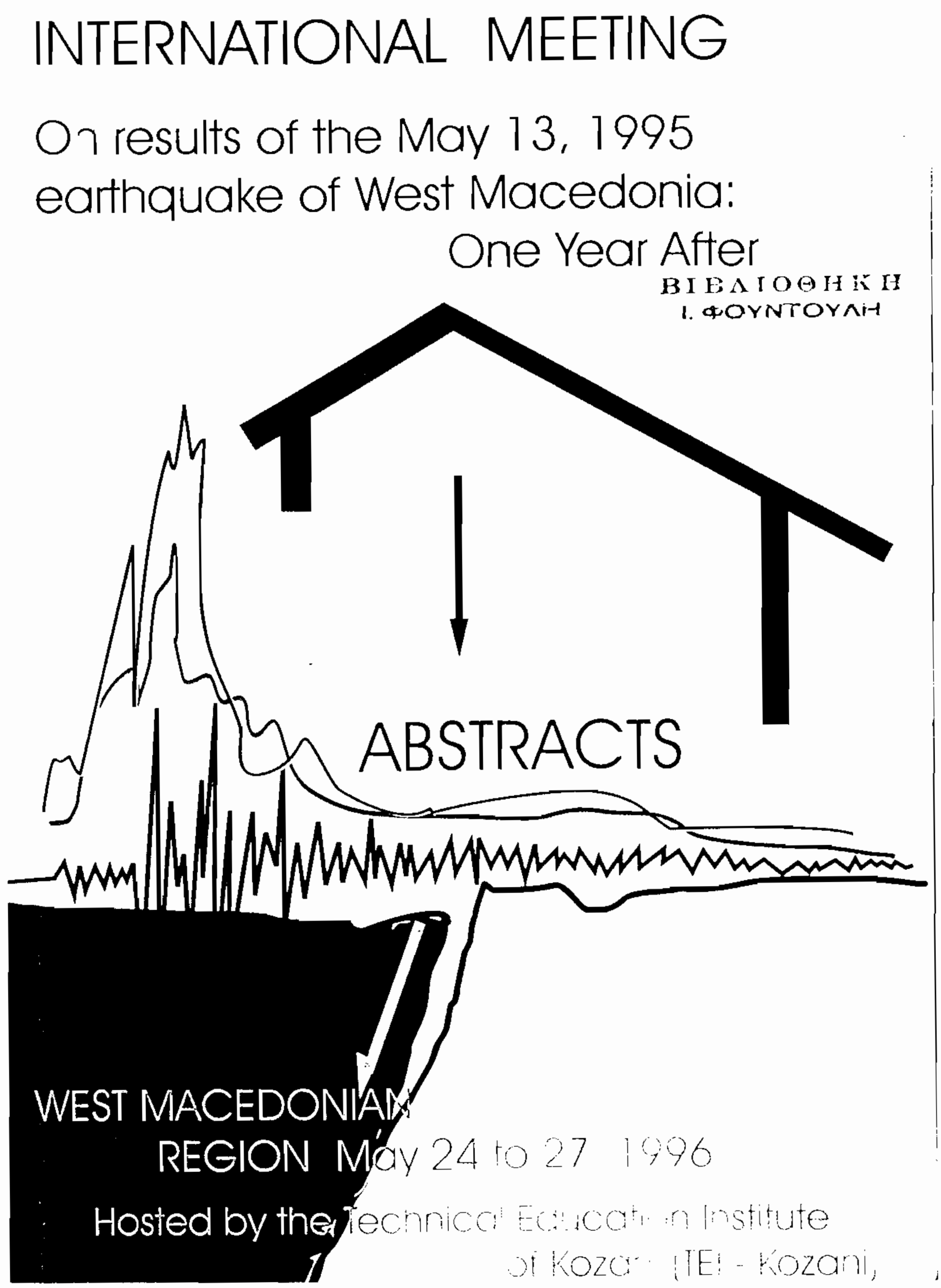
ΔΗΜΟΣΙΕΥΣΗ No 35



LEKKAS, E., KRANIS, CH., FOUNTOULIS, I., LOZIOS, S., ADAMOPOULOU E. (1996). - Spatial distribution of damage caused by the Grevena -Kozani earthquake (May 13, 1995, W. Macedonia, Greece). *In proceedings of Intern. Meeting on results of the May 13, 1995 earthquake of W. Macedonia: One Year after,* p.p. 89-95, Kozani.

International Meeting on Results of the May 13, 1995 earthquake of West Macedonia: One Year After, Extended abstracts, p.89-92

Spatial Distribution of Damage Caused by the Grevena - Kozani Earthquake (W. Macedonia, Greece) of May 13, 1995.

E. L. Lekkas, Ch. D. Kranis, **I. G. Fountoulis, S. G. Lozios** and **E. I. Adamopoulou**

University of Athens, Department of Geology, Panepisimioupoli Zografou, 157 84, Athens, Greece

Introduction

The aim of this paper is the evaluation of the damage distribution caused by the earthquake of May 13, 1995. The process followed for the evaluation of damage distribution was based on field observations and the official data collected by the prefectural authorities. It has to be noted here that the official data were to an extent unreliable, mainly because of overestimation at numerous cases. Therefore, there had to be a re-evaluation of the damage at some villages (Fig.1). The following factors were taken into account: (i) the building types present in the area, (ii) the prevailing geologic-geotechnical conditions, (iii) the morphological conditions, (iv) the occurrence of concomitant geodynamic phenomena and (v) the effects of faults and surficial ruptures.

The earthquake - regional geologic setting

The earthquake of Grevena-Kozani (Ms = 6.6) occurred at an area considered aseismic (Papazachos 1990, Papazachos et al 1995) at 11.47 local time. Its epicentre was at 40.16 N, 21.67 E and the focus lay at a depth of approximately 10 km. The shock took everybody by surprise (including the scientific community and the state) and there would have been a considerable death toll, had it not been for the fact that it was Saturday and the schools and all the civil services were closed, and the most of the people were outdoors, farming or shopping. Besides, a foreshock that occurred some minutes before the main one disturbed the residents, who sought refuge in the open air.

The pleistoseismal area is actually a broad zone trending E-W, from the northwestern border of the molassic formations of the "Meso-Hellenic Trench", through the ophiolitic complex of Mt. Vourinos and the carbonates of "Almopia" geotectonic unit, to the southern portion of the neotectonic basin of Kozani (Mavridis & Kelepertzis 1993, Papanikolaou 1986).

The western part of the pleistoseismal area represents the northeastern border of the "Meso-Hellenic Trench" which is filled with Plio-Pleistocene conglomerates, sands, clays and red soils that rest unconformably over the molassic conglomerates, sandstones and marls of Miocene age. The post-alpine formations cover the bedrock, the domination of which characterizes the geotectonic unit that consists of the Vourinos ophiolites (mostly pyroxenites, peridotites, dounites and serpentinites), thrusted over Triassic - Jurassic crystalline limestones and dolomites and transgressively covered by Upper Cretaceous limestones. Prevalent in the eastern part of the pleistoseismal area are the Pliocene lacustrine sands and marls of Kozani basin that rest unconformably over the Upper Cretaceous carbonates.

A prominent active fault ("Servia Fault") occurs at the southeastern part of the area. It strikes approximately NE-SW and juxtaposes the bedrock which, at that area comprises the Upper Cretaceous limestones, the underlying ophiolites and the pre-alpine basement of "Flambouro Unit", consisting of gneisses, augen gneisses and amphibolites. "Servia Fault" strikes NE-

SW and bears signs of Holocene activity (Pavlides et al., 1995), but it was not reactivated during the earthquake sequence.

The earthquake gave rise to a series of concomitant geodynamic phenomena, the most frequent of which was the occurrence of numerous, but subsidiary, ground fissures and seismic fractures at the villages of Knidi, Sarakina, Paleohori, Chromio, Agapi and elsewhere. Liquefaction occurred 1.5 km southwest of Rymnio, while there were numerous cases of local subsidence. Landslides and rockfalls also took place, the former at the vicinities of Agalaioi, Knidi, Rumnion, Kentron and Kalamitsi, the latter at the steep slopes near the banks of Aliakmon river and its tributaries.

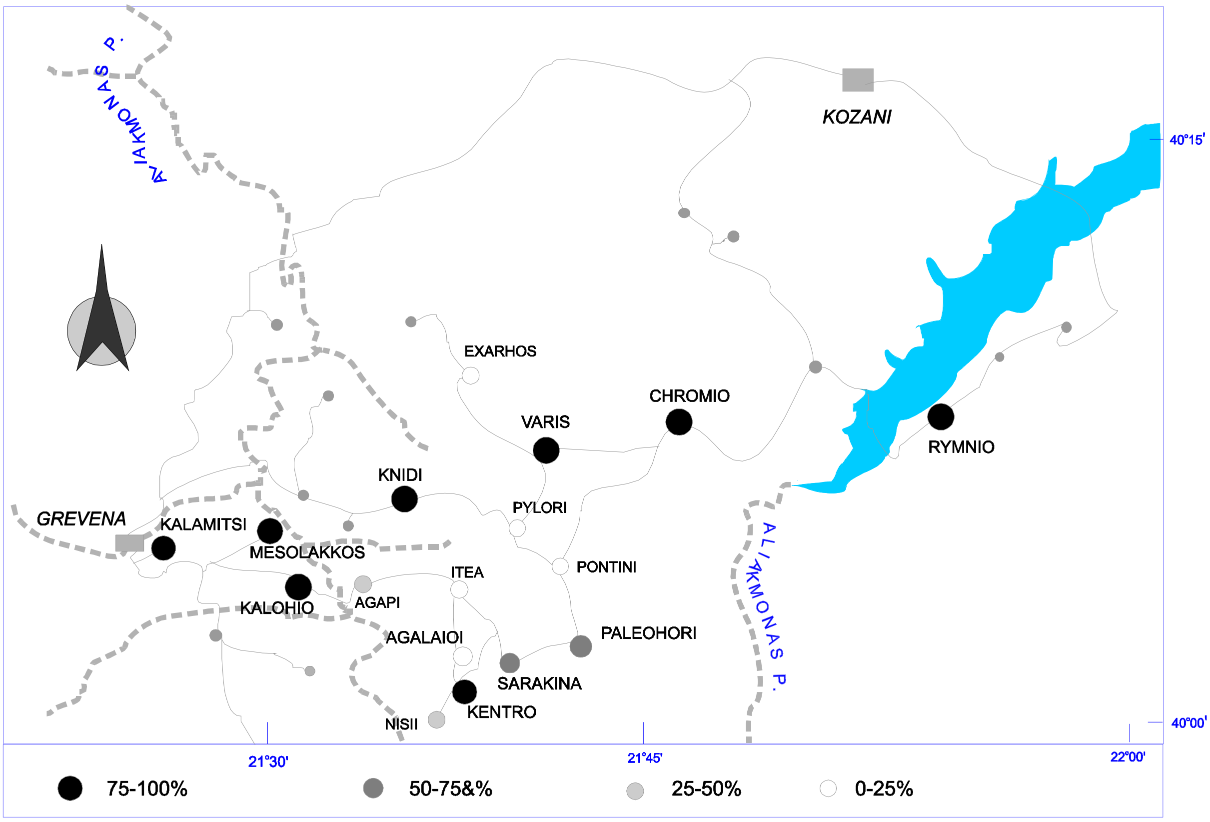


Fig. 1: Distribution of damage caused by the earthquake of May 13, 1995.

Distribution of damage

The pleistoseismal area was approximately 700 km^2 and includes 30 villages in 17 of which a lot of damages occurred. More than 1.000 houses collapsed and more than 10.000 buildings were damaged beyond repair (Fig. 1).

The building type was more or less uniform throughout the earthquake-stricken villages. Most of the houses (one- or two-story) were built of stone or masonry and fewer -and the newer ones- were built of reinforced concrete; the latter, of course, suffered much less damage than the former and the only exceptions were at the cases of mal-construction (Carydis et al 1995). At any rate, this uniformity allows for solid correlation among all the villages, regarding the distribution and extent of damage.

As regards the geologic - geotechnical foundation conditions inside the pleistoseismal area, three main cases may be distinguished: (i) houses founded on the Plio-Pleistocene sediments, (ii) houses founded on the molassic conglomerates and sandstones, and (iii) houses built on a thin soil mantle developed on the alpine bedrock.

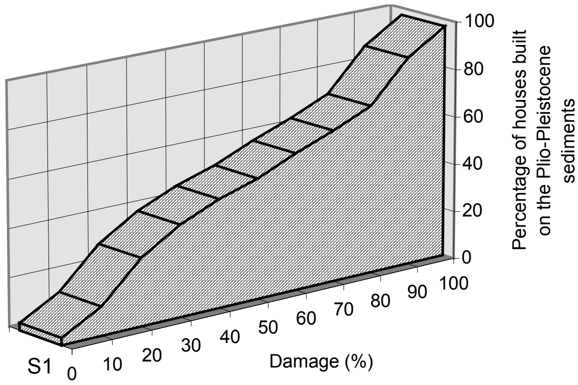


Fig. 2: Percentage of houses per village built on the Plio-Pleistocene sediments.

This seemed to be the decisive factor in the distribution of damage. The more a village was founded on the Plio-Pleistocene formations, the greater the damage (Fig. 2). On the other hand, at the cases when a village was founded on molassic conglomerates and sandstones, or, better still, on the alpine bedrock, the damage was significantly reduced (Lekkas et al 1995). Besides, the existence of shallow aquifers in the loose Plio-Pleistocene sands and gravels deteriorated the situation. Thus, the vast majority of the totally collapsed villages lies at the western part of the pleistoseismal area, where most of the Plio-Pleistocene formations occur. It has to be noted that, apart form the villages in the western part (Kalamitsi, Mesolakkos, Kalohi, etc.) there was another group of seriously damaged ones; the latter lay along the trace of the "Kentro-Paleohori Fault", which seems to be the southwestern prolongation of the "Servia Fault" and presented no surficial rupture. It is only identifiable by the distinct scarp it has produced.

Quite diverse too, were the morphologic conditions throughout the area. This morphologic diversification played a key role in the occurrence of landslides and rockfalls. However, it is not in direct link with the extent of the damage. As shown in Fig.3 there are villages built on flatlands and they were completely razed (e.g. Knidi) and others that despite the adverse morphological conditions suffered limited damage.

The fractures caused by the earthquake can be split into two groups. The first one comprises the fractures that occurred as a by-product of the reactivation of the fault zone of "Kentro-Paleohori". They all had similar characteristics, namely a length of some tens of cm to a few metres and N70° to N100° strike, and lie along the trace of the fault zone. At cases, they occurred in en echelon arranged sets (e.g. a few hundreds of meters north of Sarakina). The second group comprises E-W striking fractures, all found along a broad zone, from Knidi to Chromion. These fractures reached at cases several metres or hundrent of metres in length. In all, it may be said that the occurrence of fractures and minor fissures did not seem to affect particularly the distribution of damage.

Discussion - Conclusions

The earthquake of Grevena- Kozani was a devastating one; thousands of people remained homeless and the social infrastructure was severely struck. The pleistoseismal area has almost non-existent earthquake history, despite the fact that a prominent active structure runs next to it. At any rate, though, this structure was not reactivated, or at least the visible segment of it. The distribution of damage was heavily dependent upon the prevailing geologic - geotechnical conditions, with all the other factors playing a lesser role. Particular care has to be taken in the reconstruction or the rehabilitation of the villages, as the loose Plio-Pleistocene sediments are very susceptible to failure by an eatrhquake.

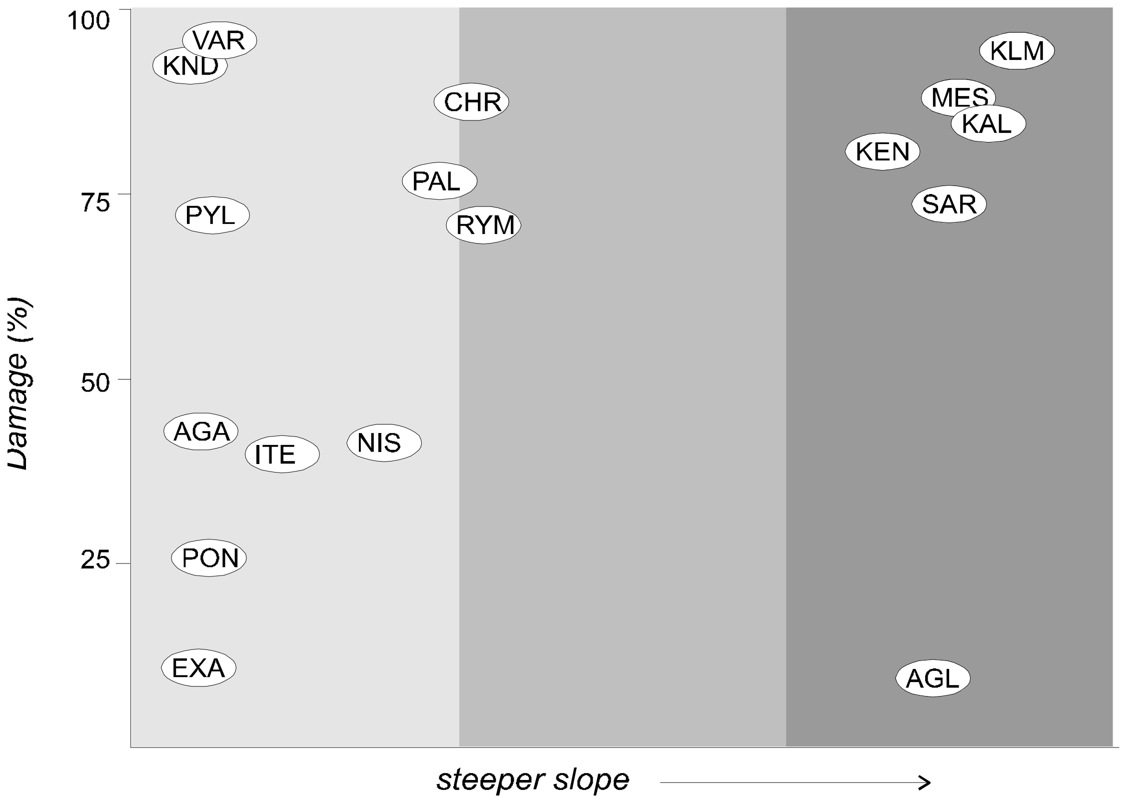


Fig. 3: The relatioship between the extent of damage and the morphological prevailing morphologican conditions at each village. Light gray area = flatlands or areas with smooth relief; medium gray area = areas with moderately-steeping slopes; dark gray area = areas of relatively high relief. The villages plotted on the boundary between two areas present a "dual" morphology (eg. part of the village built on flatlands and part on a slope). AGA=Agapi, AGL=Agalaioi, CHR=Chromio, ITE=Itea, EXA=Exarchos, KND=Knidi, KAL=Kalohio, KLM=Kalamitsi, KEN=Kentro, MES=Messolakos, PAL=Paleohori, PON=Pontini, PYL=Pylori, RYM=Rymnio, SAR=Sarakina, VAR=Varis, NIS=Nisi.

References

Carydis,G., Holevas,K., Lekkas,E. & Papadopoulos,T. (1995): The Grevena (Central-North Greece) Earthquake Series of May 13, 1995. EERI Spec. Earth. Rep., Vol. 29, Nb 6, 1-4.

Lekkas,E.L., Lozios,S.G., Fountoulis,I.G., Adamopoulou,E.I. & Kranis,H.D. (1995): Investigation - Correlation of the geodynamic hazards at the earthquake stricken areas of Kozani - Grevena: Proposals for safe reconstruction, Applied research Project, Athens. 1995.

Mavridis,A. & Kelepertzis,A. (1993): Geological map of Greece, scale 1/50.000, "Knidi" Sheet, I.G.M.E. Publ.

Papanikolaou,D. (1986): Geology of Greece. 240 p., Athens 1986.

Papazachos,B.C. (1990). Seismicity of the Aegean and surrounding area. *Tectonophysics*, 178, 287-308.

Papazachos, B.C and twelve others (1995): The physical generation process of the Kozani-Grevena earthquake of 13 May 1995 (Ms=6.6) and the ensuing earthquake sequence. Publication No. 4, 1995, Aristotle University of Thessaloniki.

Pavlides,S.B., Zouros,N.C., Chatzipetros,A.A., Kostopoulos,D.S. and Mountrakis,D.M. (1995): The 13 May Western Macedonia, Greece (Kozani Grevena) earthquake; preliminary results. *Terra Nova*, 7, 544-549.