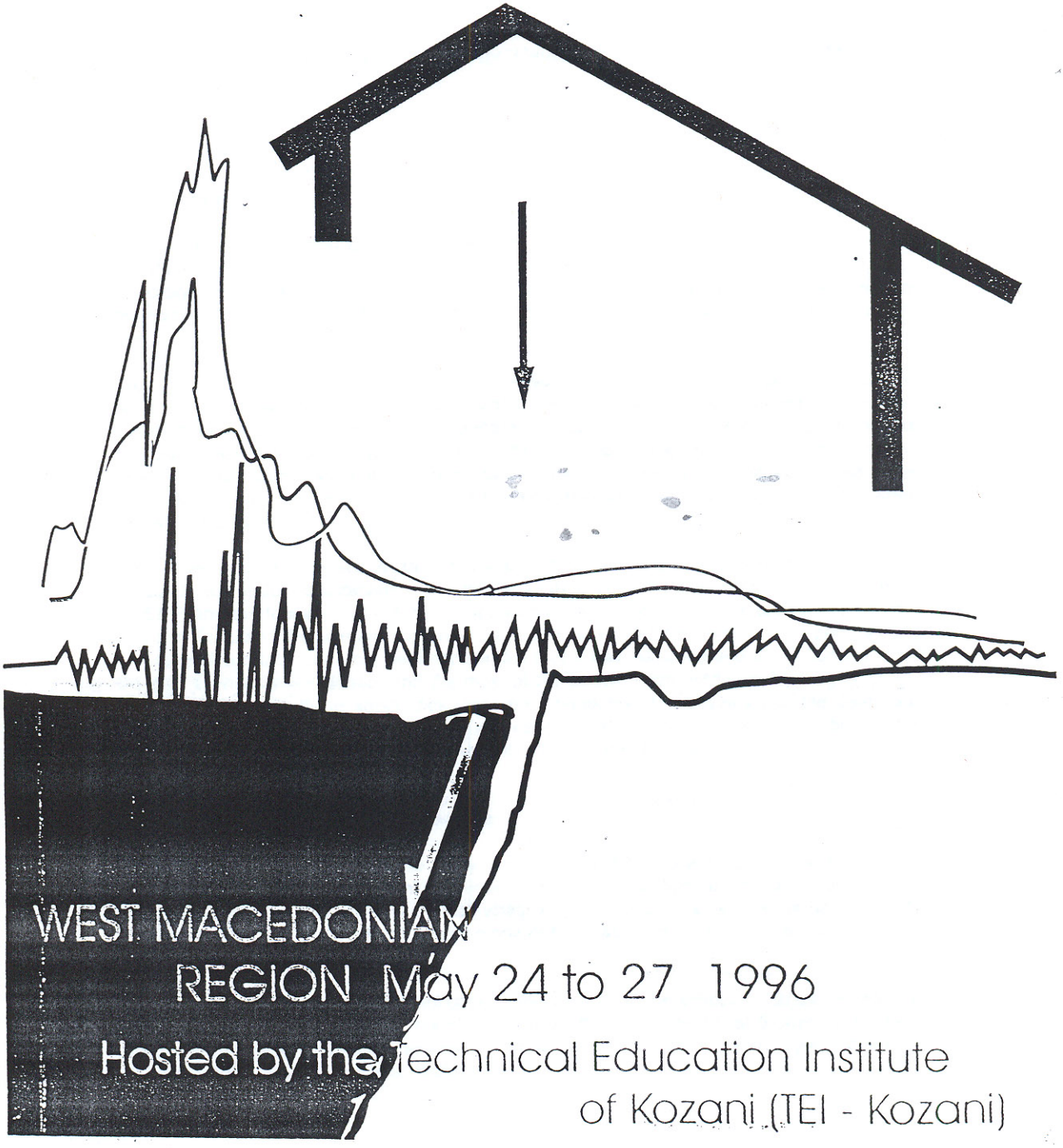
INTERNATIONAL MEETING

On results of the May 13, 1995 earthquake of West Macedonia: One Year After



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Neotectonic Implications of Grevena - Kozani Earthquake (May 13, 1995, W. Macedonia, Greece)

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Introduction

The Grevena - Kozani area was considered up to now as one of the most seismically inactive areas in Greece (Papazachos 1990, Papazachos et al 1995). On May 13, 1995, an earthquake of Ms=6.6 occurred, which caused many damages in a part of Kozani city and in some villages located between the cities of Grevena and Kozani (Carydis et al 1995, Lekkas et al 1995).

The damage has been limited to relatively small area in the form of a triangle extending between the Serbia fault zone to the south, and the Chromion - Varis fault zone to the north (Fig. 1). The western limit was the Aliakmon river. The severe damage is mainly located at the villages lying at the foot of Mt. Vourinos, and some others, as Rymnio and Chromio. However, there still is an “eclectic” distribution, with two groups of highly damaged villages, one at the north (Knidi, Varis, Chromio) and the other at the south (Paleohori, Sarakina, Kentro, Messolakos, Kalamitsi and Kalohi).

The recent earthquake have also caused a series of concominant geodynamic phenomena, the most frequent of which was the occurrence of numerous, but subsidiary, ground fissures at the villages of Knidi, Sarakina, Paleohori, Chromio, Agapi and elsewhere. Liquefaction occurred 1.5 km east of Rymnio (Pavlides et al 1995), while there were numerous cases of local subsidence. Landslides and rockfalls also took place, the former at the vicinities of Agalaioi, Knidi, Rimnio, Kentron, and Kalamitsi, the latter at the steep slopes near the banks of Aliakmon river and its tributaries (Fig. 2). In this paper we discuss the kinematics and dynamics of this fracturing based on the neotectonic evolution of the area.

Morphology

The pleistoseismal area can be divided into three morphologic units, namely of Kozani, Mt. Vourinos and Grevena. The Morphologic units of Kozani and Grevena present a relatively smooth relief, with characteristic planation surfaces developed either over the molassic formations of the Meso-Hellenic Trench, or the Plio-Pleistocene sediments.

The morphological unit of Vourinos presents quite intense relief, has a general NW-SE trend and is located between the previous two. At places it is interrupted by E-W trending plateau; that is the case of the area of Knidi-Varis-Chromio (Fig. 1).

The drainage pattern belongs to Aliakmon river, which, as already mentioned actually forms the southern and western boundary of the pleistoseismal area. Certain smaller-order tributaries, especially these flowing at the morphologic units of Kozani and Grevena, are incised.

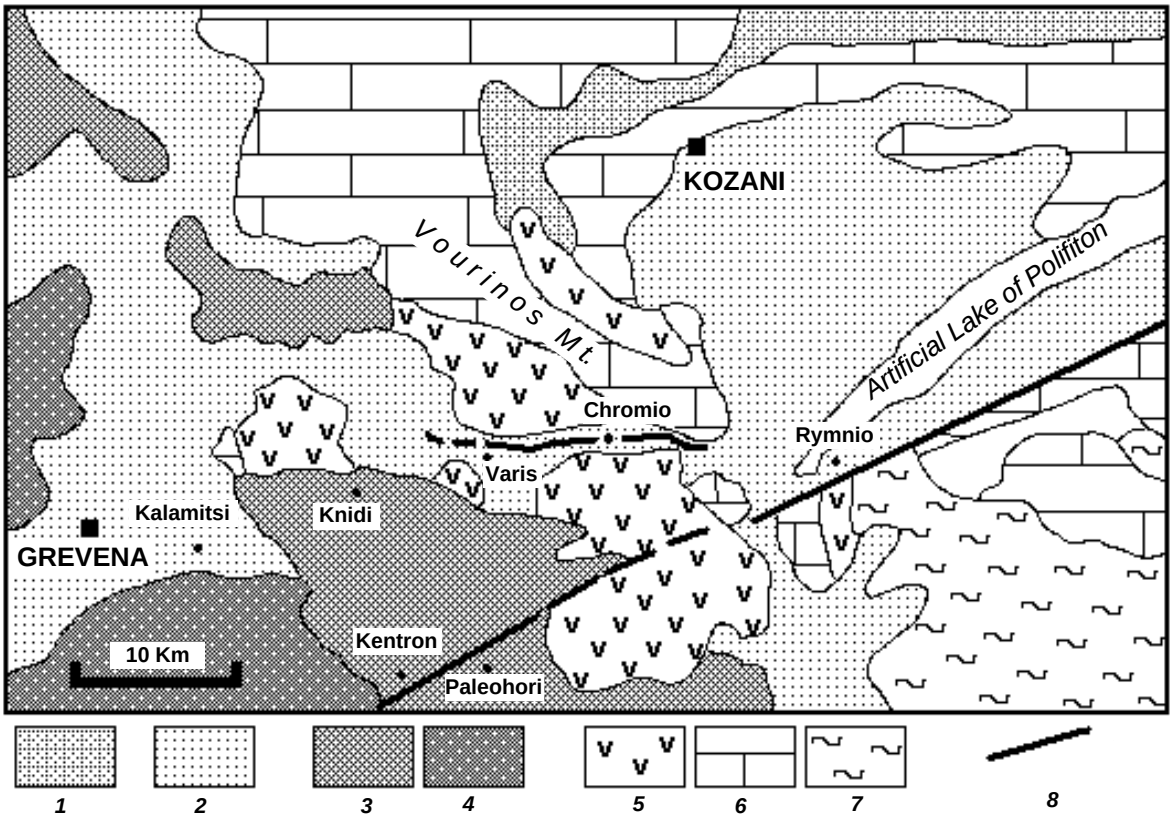

Fig. 1: Simplified Geological Map of the earthquake striken area (1: Alluvial and Scree, 2: Plio-Pleistocene sediments, 3: "Tsotylion" molassic formation, 4: "Pendalofo" molassic formation, 5: "Vourinos" ophiolitic complex, 6: "Eastern Greece" carbonates, 7: "Flambouron" gneisses and schists, 8: fault zones.

Geotectonic Setting - Regional Geology

The earthquake stricken area forms a E-W trending zone, from the northwestern border of the Meso-Hellenic Trench at the west, runs through the southern part of the ophiolitic complex of Mt. Vourinos and the carbonates of “Eastern Greece Unit” and ends at the southern part of the post-alpine basin of Kozani. The following formations (Fig. 1) occur in the area (Papanikolaou 1986, Mavrides & Kelepertzis 1993):

POST-ALPINE FORMATIONS.

Alluvial deposits - Scree: The alluvials develop mainly along the main streams and torrents and consist of sands, gravels, pebbles and loose, in general material. The scree and talus cones develop mostly on the eastern and western slopes of Mt. Vourinos and consist of unconsolidated multimictic breccias.

Plio-Pleistocene deposits: They occupy the whole of the basin of Kozani, but also occur to a great extent at the wets of Mt. Vourinos, around Grevena, where they lie unconformably over the molassic formations of the Meso-Hellenic Trench. The comprise consolidated conglomerates, sandstones, sands, red soils, loose conglomerates, clays and unconsolidated sandstones. They are fluvial and lacustrine deposits, the former dominating at the western part (Grevena) and the latter at the east (Kozani). It should be mentioned that Eltgen (1986) describes the occurrence of marine Pliocene deposits at the region between Askion Mt. and Pindos mountain range, and more specifically at the

area of Neapolis. He suggested, based on planctonic and benthic foraminifera, that the Pliocene sediments are marine deposits, and the Pleistocene consists of continental deposits. Nowadays the marine Pliocene deposits are found at an altitude of 700 m. at the area of Neapolis.

MOLASSIC FORMATIONS OF THE MESO-HELLENIC TRENCH

Two members of the Molassic sequence occur in the area, namely the Tsotyli and Pentalofos formations.

Tsotyli formation: It occurs at a broad, NW-SE trending band along the western flanks of Mt. Vourinos; the main outcrops are to the south of Knidi. It comprises alternations of conglomerates, sandstones and thin layers of marls of Bourdigalian age. Near its base and close to the contact with the ophiolites of Vourinos, molassic conglomerates are dominant, and gradually pass on to alternations of sandstones, marls, sandy marls and conglomerates.

Pentalofos formation: It occupies the western part of the area and its main outcrops are found to the NW and Se of Grevena. It consists of multimictic conglomerates which pass on to alternations of conglomerates, clays and sandstones of Aquitanian age.

ALPINE FORMATIONS

Mt. Vourinos ophiolitic complex: The members of the ophiolitic complex are mainly located at the NW, and to a lesser extent, at the NE part of Mt. Vourinos; besides there are smaller occurrences to the east of Grevena and north of Knidi. The outcrops at the mountain comprise the lower members of the complex, namely pyroxenites, peridotites, dunites and serpentinites. The outcrop of Grevena consists of the upper members, that is peridotites, gabbro, diorites, dacites and lavas.

"Eastern Greece Unit" carbonates: They crop out at the central and northern part of Mt. Vourinos, as well as at the eastern portion of the study area. They comprise limestones and dolomites of Triassic-Late Cretaceous age and they either underlie (Triassic - Jurassic) or cover transgressively (Upper Cretaceous transgression) the ophiolitic complex. In the former case the contact is tectonic (thrust). The Triassic-Jurassic parts consist mainly of crystalline limestone and dolomites, while the Late Cretaceous ones comprise unbedded brecciated and thin-bedded marly limestones, and more rarely calcitic-marly sandstones.

Metamorphic formations of "Flampouro Unit": They occur at the SE part of the area and comprise augen gneisses, gneisses and amphibolites.

Tectonics - Neotectonics

Three main tectonic macrostructures can be distinguished in the pleistoseismal area (i) the eastern margin of the Hellenic Trench, to the east of Grevena, (ii) Mt. Vourinos unit in the middle, and (iii) the basin of Kozani, further to the east, which is juxtaposed against the macrostructure of Vourinos through a NW-SE fault zone. The southern margin of Kozani basin is bounded by the Servia fault, and further to the south there are the mountains of Kamvounia and Titaros. Servia fault is active, and bristles with signs of late activity, as impressive slickensides, the well developed scree and a prominent composite scarp; however, this segment was not reactivated during the earthquake of 13 May 1995.

The south-western prolongation of Servia fault is the Kentro-Paleohori fault zone, running through the villages of Paleohori, Sarakina and Kentro, all of which suffered severe damage. This segment is recognised mainly through the scarp is has produced in the post-alpine sediments.

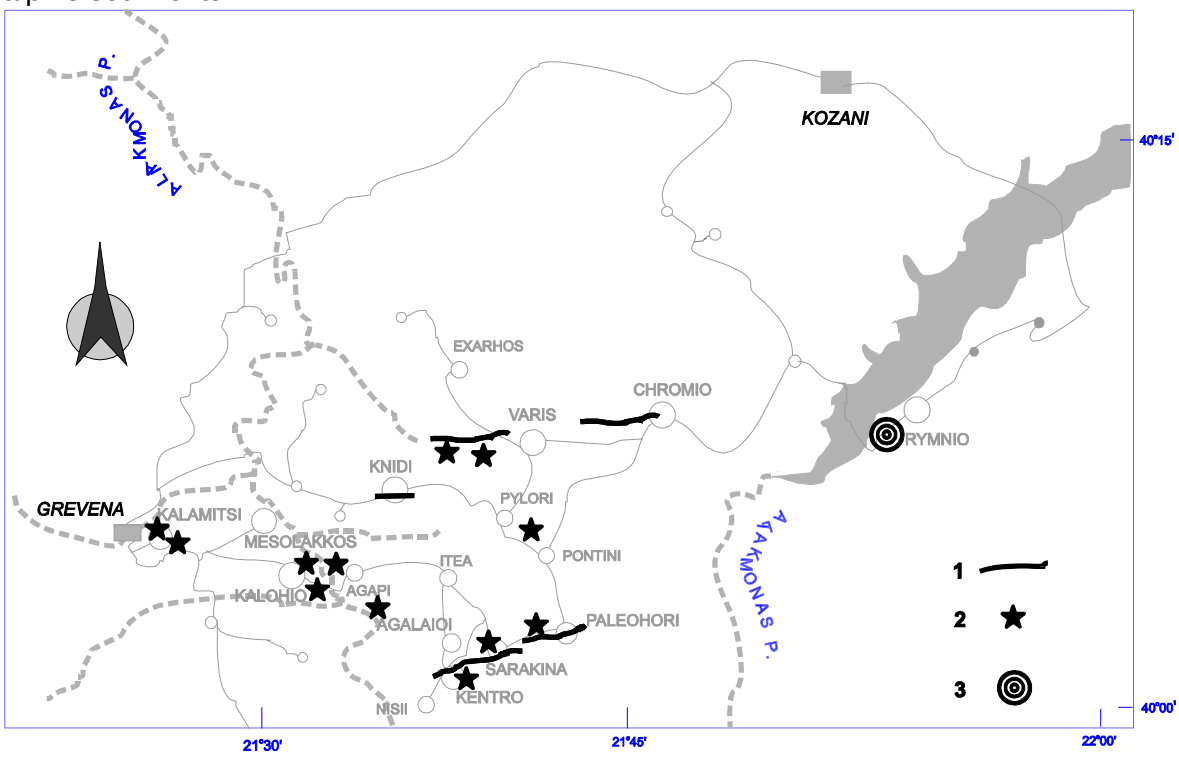

Fig. 2: The localization of the seismic fractures (1), landslides (2) and liquefaction phenomena which occurred during the Grevena-Kozani earthquakes.

Few faults, with NW-SE and E-W directions, are visible in Vourinos and the area around Grevena. It has to be noted that certain NW-SE and ENE-WSW trending lineations have been found in the area of Vourinos. They have been recognised either through geological criteria (juxtaposition of quaternary formations) or through aeromagnetic anomaly interpretations and could be possibly faults (Mavridis & Kelepertzis 1993). One of these is the lineation of Chromio - Varis, which in all probability is a fault zone and intersects the fault zone of Servia at the vicinity of Rymnion.

During the recent seismic activity few faults and fractures bearing signs of reactivation were found. Also, certain phenomena, as landslides, settlement as well as local distribution of damage that developed in a linear fashion may mark the reactivation of some faults. One of these cases was the Kentro-Paleohori and the Chromio-Varis fault zones. Especially as regards the former few en echelon (right lateral) arranged fractures (E-W strike) were found at the location of Agios Athanassios). At the remainder of the area the earthquake fractures were sparse, though the majority of them had the same E-W strike; a representative case was inside Knidi, with a length of at least five meters and a slight vertical offset (downthrown northern part)

Discussion

In order to comprehend the ongoing geodynamic procedures in the area, we need to bear in mind the following remarks:

- There is a clear aeromagnetic E-W anomaly between Chromio and Varis, which has been interpreted by Pavlides (1985) as a dextral strike-slip structure of Miocene age.
- Most of the earthquake fractures found were arranged in dextral strike-slip fashion, at most cases their vertical offset was negligible or nil.
- The occurrence of reverse faults, as shown by Faugeres & Vergely (1974), who describe (i) on the 12th km of the road from Aiani to Skoumtsa, the reverse fault ($45^0/230^0$) that brings in contact the schist-chert formation (hanginwall) with the Pliocene conglomerates (footwall) and (ii) at a gorge to the south-east of Dafnero, another reverse fault ($45^0/240^0$) whose footwall consists of early Pliocene sediments and its hanginwall consists of molassic formations. The throw of both faults is more than 20 m and their ages are Upper Pliocene and Lower Pleistocene, respectively.
- The occurrence of folds and reverse faults in the basin of Kozani (Pavlides 1985).
- The fact that the marine Pliocene deposits at the basin of Neapoli, Grevena are found at an altitude of 700 m. (Eltgen, 1986)

Therefore, and taking into account all these, we come to the following conclusions:

- The neotectonic activity in the area has been expressed both through vertical and horizontal movements since the Pleistocene.
- The deformation during Quaternary shows the existence of a composite stress field, with local expressions of extension and compression and the occurrence of both brittle and ductile structures.

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