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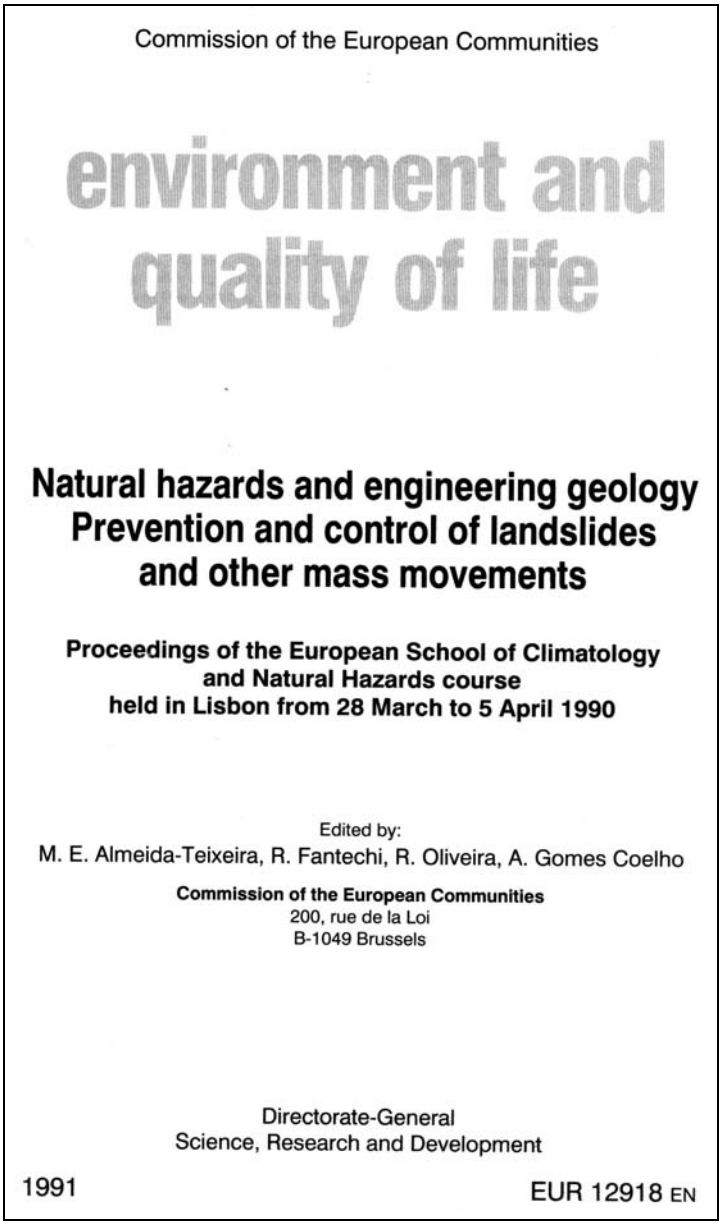

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SOIL FRACTURES AND SAND WATER'S SHAKING OFF OBSERVED DURING THE EARTHQUAKE OF OCTOBER 16th, 1988 AT THE REGION OF VARTHOLOMIO (W. PELOPONNESUS, GREECE)

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Summary

Soil fractures and sand water's shaking off observed during the seismic activity of the October 16th, 1988 at the Bouka Vartholomio region (W. Peloponnesus, Greece), are described. They are quite impressive and relatively rare phaenomena due to the earthquake movements occured and the special geological conditions of the area. The soil fractures have quite particular directions and they are developped on a rather inflexible and compact formation, that overlays a loose, water bearing formation. Water and sand have been ejected through these particular fractures. This is due to the liquefaction phaenomena and the free setting of water due to the decrease of the effective porosity.

I INTRODUCTION

In October 16th, 1988 the major area of Kyllini peninsula and Zakynthos island were affected by an earthquake of M_S=6.0 R. which caused many damages mainly in the area of Kyllini peninsula (fig. 1).

In the same time with the main shock, soil fractures and sand water's shaking off phaenomena were observed.

The area, located 5km southern of Vartholomio village, lies 4m above the sea level and it's extension is about 10.000km^2. The area is bounded from the eastern by Pinios river, western by a farming road which connects Vartholomio village to the seashore, northern by a swampy zone whose width is 10m and southern by the coastal dunes.

After the observation of the sand water's shaking off phaenomena the following works were done:

a. A detailed mapping and registration of the specific characteristics of the soil fractures.
b. A detailed mapping and discription of the observed sand water's shaking off points.
c. Some shallow sampling drillings.

II GEOLOGY

The alpine formations consist the basement and belong to the Ionian geotectonic unit. More specifically evaporites possibly of Triassic age occur at the Kastro village area as well as sub-white thick bedded limestones possibly of Cretaceus to Eocene age (fig. 2).

The post-alpine formations overlay unconformably the alpine formations and they outcrop all over the regional area. They can be distinguished into

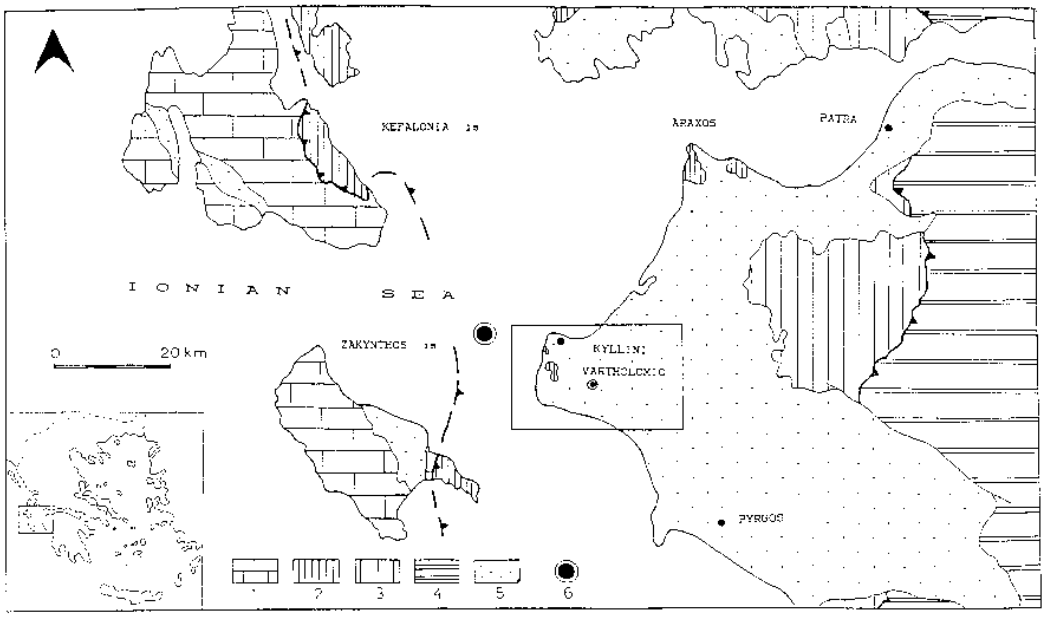

fig. 1 General geological map of the major area. The following geotectonic units are distinguished: 1: Paxoi Unit, 2: Ionian Unit, 3: Gavrovo-Pylos Unit, 4: Pindos Unit, 5: Post-alpine sediments, 6: Epicenter.

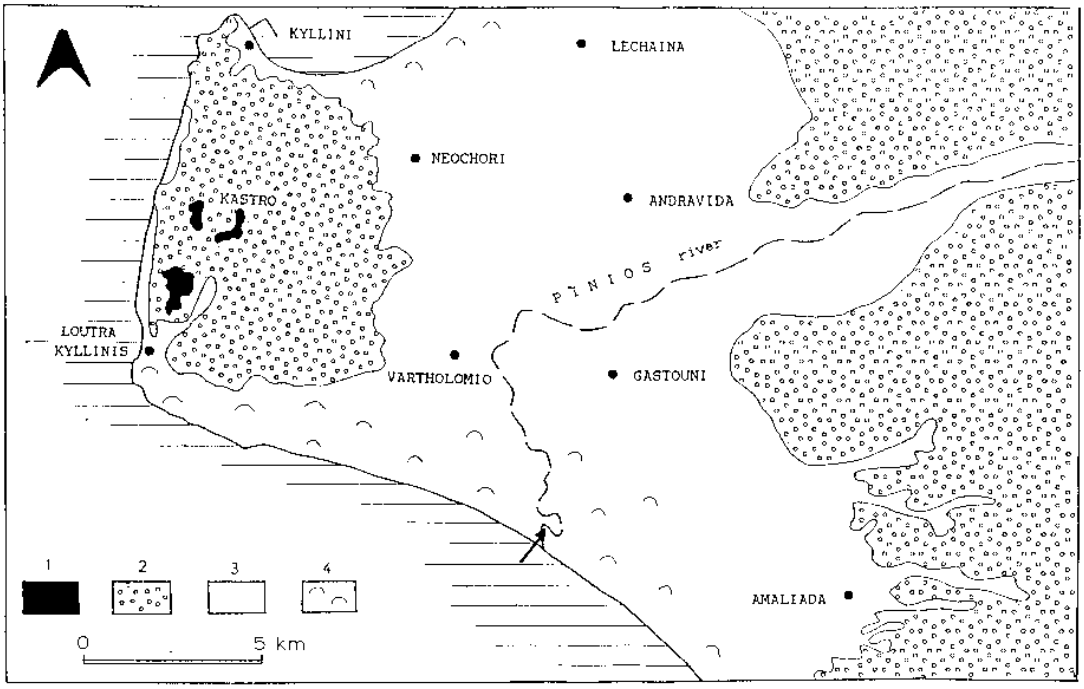

fig. 2 Simplyfied geological map of the regional area in which soil fractures sand water's shaking off phaenomena were observed. Their position is pointed with the arrow. 1: Alpine formations of the Ionian Unit, Plio-Pleistocene formations, 3: Alluvial deposits, 4: Dunes.

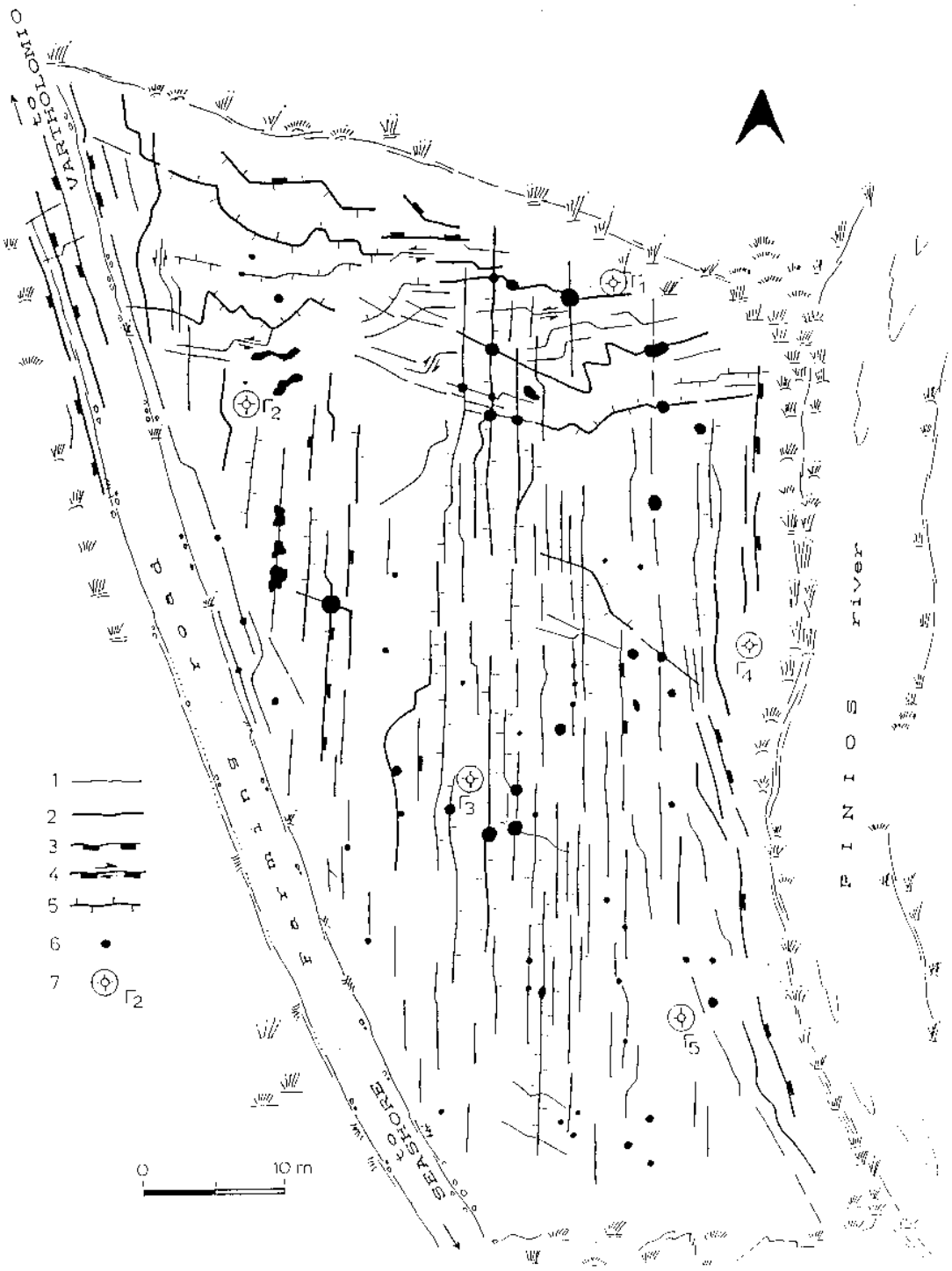

fig. 3 Soil fractures and sand water's shaking off map of the Bouka (Vartholomio) area. 1: Soil fracture. 2: Soil fractures with wide openning. 3: Soil fractures with vertical throw. 4: Soil fracture with horizontal conponent of displacement. 5: Sand water's shaking off along soil fracture. 6: Crater. 7: Shallow drilling points.

two big groups, marine sediments and continental deposits (fig. 2).

The marine sediments are of Plio-Pleistocene age and consist of sandstones, sands, clay,silt and some intercalations of thin bedded lignitic layers. Their thickness, in this region, is up to 1500m according to drilling and geophysical data (HAGEMAN 1977, KOWALCZYK & WINTER 1979, KAMPERIS 1987).

The continental deposits are of Holocene age consisting of sands, gravels, and clay. They outcrop in the flat area between the villages, Lechaina, Andravida,Gastouni and Vartholomio (fig. 2).

In the coastal area between Loutra Kyllinis and Bouka area , only dunes outcrop.

The main neotectonic macrostructure of the area is a tectonic graben. The axis of the tectonic graben - as it has been confirmed from deep drillings as well as from the intrpretation of the geophysical data (KAMPERIS 1987) - strikes N-S and is located 4 to 4.5km east of the intelligble line Lechaina - Andravida - Gastouni (fig. 2).

III DESCRIPTION OF THE PHAENOMENA

1. The Soil fractures

The specific characteristics of the soil fractures which were mapped in detail (fig. 3) are the following:

a. The length of the soil fractures fluctuates from some centimeters to few tens of meters. Most of them are in a staight line, without being absent the curved one. Very often these fractures cut each other.

b. The width of the fractures fluctuates from a few to 40 cm. The largest in width fractures were observed at the eastern part very close to Pinios river and at the northwestern part along the farming road.

c. The visible depths of the fractures are more than 40cm. In most cases the empty space of the fractures was filled from soil material which fell down from both sides of the fracture.

d. As it is shown in the rose diagram of the soil fractures, four groups can be distinguished (fig. 4).

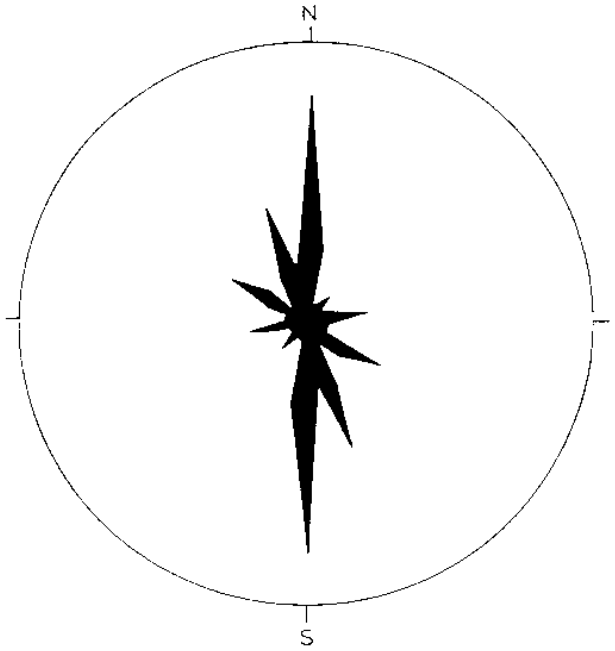

fig. 4 The four groups of the soil fractures.

e. At some soil fractures or at some parts of them a vertical throw of 5 to 10cm can be observed.

f. At some parts of the soil fractures dextral or sinistral horizontal displacement up to 5cm can be observed.

2. The sand water's shaking off phaenomena

During the earthquake of October 16th, 1988, simultaneusly with the creation of the soil fractures, very impressive sand water's shaking off phaenomena were observed. The sand water's shaking off was made through:

i) Craters created along soil fractures.

ii) Craters that were in the intersection of two or more soil fractures.

iii) Along the whole length of the soil fractures or along a part of them.

iv) Lonely craters or group of craters.

More specifically:

a. The craters along the soil fractures had a diametre up to 40cm.

b. Craters that were in the intersection of two or more fractures had a diametre from 60cm to 100cm.

c. Craters which were not connected with soil fractures had a relatively small diametre.

3. Shallow drilling data

In order to make well understood the sand water's shaking off phaenomena, five shallow sampling drillings were made the position of which is shown in fig. 3. Three more shallow sampling drillings were also made in the surrounding area.

The grain size distribution graphs from the sampling of the five shallow drillings (fig 5 and 6), the following remarks can be done:

a. From the ground surface up to 50cm depth there is a red-brown coloured formation which consists of fine grain sand, silt and clay. The precise composition of this upper formation is shown in the grain size distribution graphs in fig. 6a, resulting from the grain size analysis of the samples. This upper formation is not homogeneous.

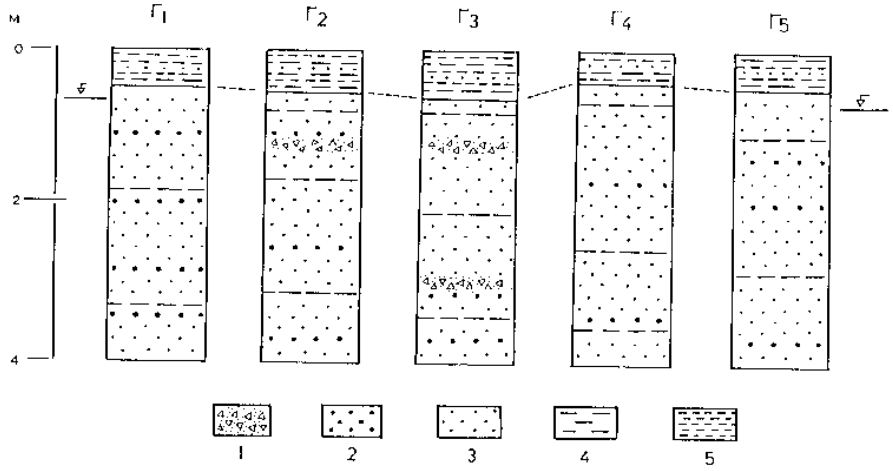

fig. 5 The lithostratigraphic collumns of the shallow drillings Γ1 - Γ5.
1: Gravels, 2: Medium coarse sand, 3: Fine sand, 4: Silt, 5: Clay

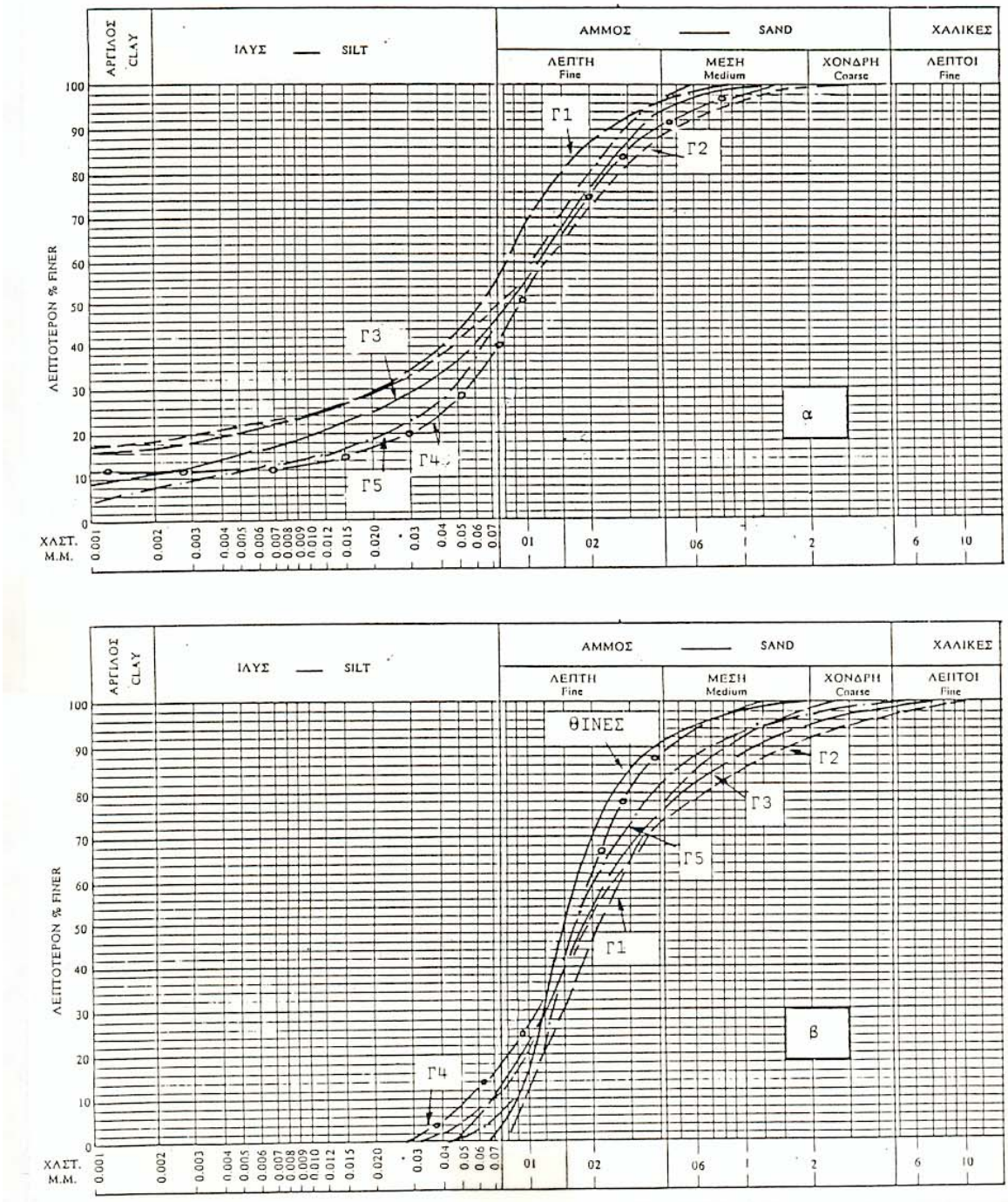

fig. 6 Grain size distribution graphs of the samples of the shallow drillings (Γ1 - Γ5) for the upper formation (a) and for the lower formation (b). There is also the grain size distribution graph of the samples from the adjacent dunes.

b. Below this groundsurface formation and up to 4m depth, there is another formation, the main characteristic of which is the presence of coarse grain sand (red-brown in color) with some ntercalations of thin-bedded silt. This formation is homogeneous and it's precise composition is shown in the grain size distribution graphs in fig. 6b. This formation has the same characteristics with the grain size distribution graph of the coastal dunes (fig.6b).

The other three shallow sampling drillings showed that the thickness of the uppper formation in the surrounding area was more than 4m.

IV DISCUSSION AND INTERPRETATION OF THE PHAENOMENA

As it has been refered the soil fractures and sand water's shaking off phaenomena were observed in a small area. The fractures were observed in the upper surface formation and they can be distinguished in four groups.

The Ist order group of the soil fractures that has high frequency and big length strikes N-S. This direction coincides with (i) the direction of the big axis of the tectonic graben, (ii) the direction of the seismic fractures that were observed on the limestones of the Ionian geotectonic unit at the Kastro village area.

The IInd order group of the soil fractures strikes NNW-SSE and is parallel to the bank of Pinios river. Their creation ought to be the result of the bank instability and this is the reason why wide openings were observed.

The IIIrd order group of the soil fractures strikes NW-SE and was occured in the northen part of the area, mainly parallel to the swampy zone.

The soil fractures were observed only in the upper and not in the lower formation. The main reason for this selective presence of the soil fractures in the upper formation is that this fomation is more compact and relatively more inflexible than the lower one that is more flexible with presence of water phase.

The question rising now is, which is the reason for the creation of the soil fractures and the sand water's shaking off phaenomena?

It is believed that the main reason for the creation of all the above mentionned (soil fractures, sand water's shaking off) was the seismic shock in combination with the different formations which occur in this particular area. More specifically the seismic movement had as result the liquefaction of the sands of the lower formation, so the lower formation in its whole or in its big parts behaved as a heavy liquid. As it is known liquefaction phaenomena take place when loose sands or silty sands are under shear repeated deformation (f.e. seismic wave).

In the same time the seismic movement had as result the efficient decrease of the effective porosity of the lower formation (mainly sands) because of the more compact arrangement of the grains. The decrease of the effective porosity unbinded the water which was under pressure because of the weigth and the relative impermeability of the overlying upper formation. In the same time, the creation of the fractures at the upper formation made easy the water's shaking off upwards, which carried material from the lower formation.

The water's shaking off velocity was controlled mainly by the size of the fractures as it can be concluded by the clastic material deposited around the exits.

The water's horizontal movement possibly was restrained by the obstruction (blocking up) of the pass, because of the degradation of the side parts, even the occurance of the clay or silt from the Pinios river deposits.

The sand water's shaking off was locally reinforced by the creation of

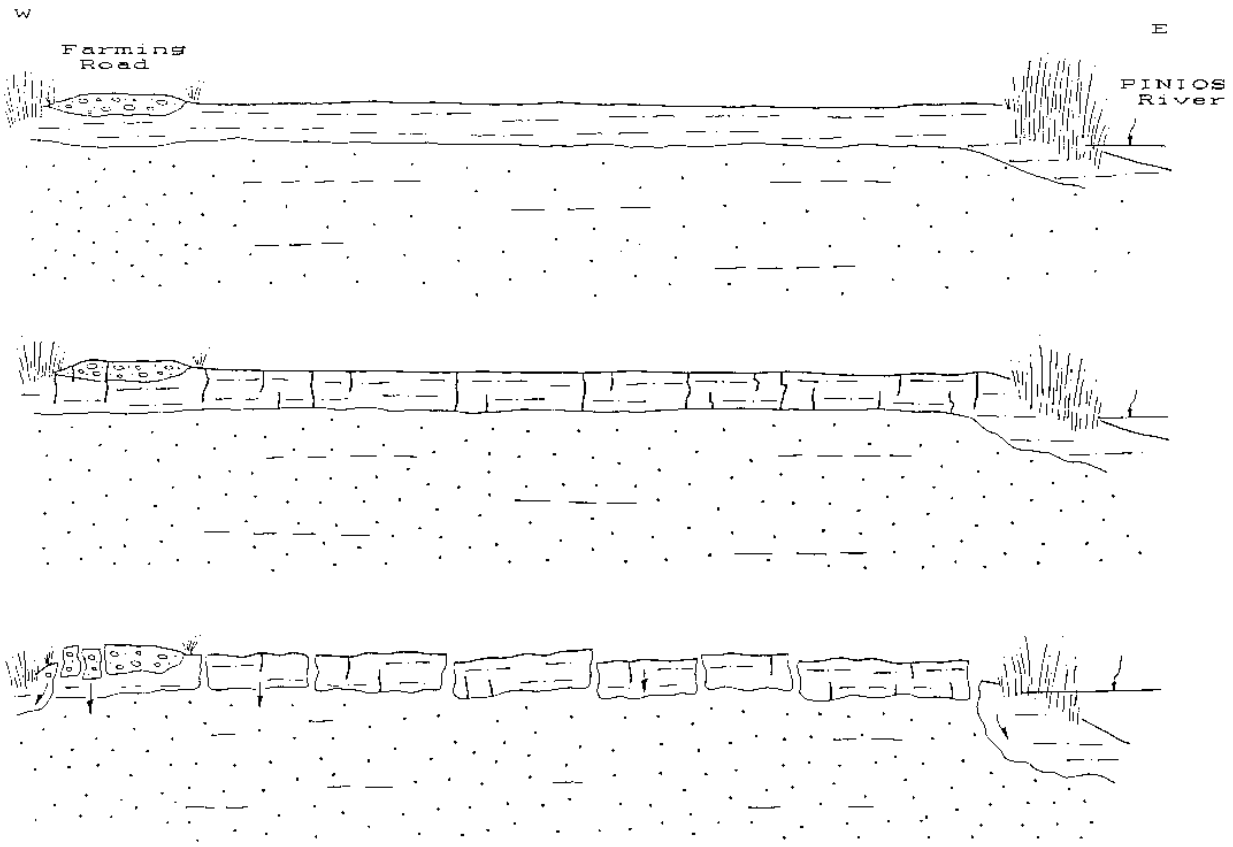

fig. 7 Schematic interpretation of the sand water's shaking off mechanism during the earthquake of October 16th, 1988, at the Bouka (Vartholomio) area. The relatively compact and impermeable upper formation is visible as well as the relatively loose and permeable lower formation.

independent microblocks in the upper formation because of the soil fractures which bounded these microblocks (fig. 7).

Concretely some microblocks were under conditions of instability which had as result the falling down or the rotation of them, a fact that can be recognised from the small vertical throws or the horizontal displacement. The relative downwards movement (subsidence) of some blocks of the upper formation helped the water's shaking off upwards.

The absence of sand water's shaking off along the soil fractures on the farming road is possibly connected with the lower water bearing of the lower formation - because of the artificial condensation - from the works of filling up the farming road and the relative higher (about 30 - 40cm) position compared with the surrounding area.

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