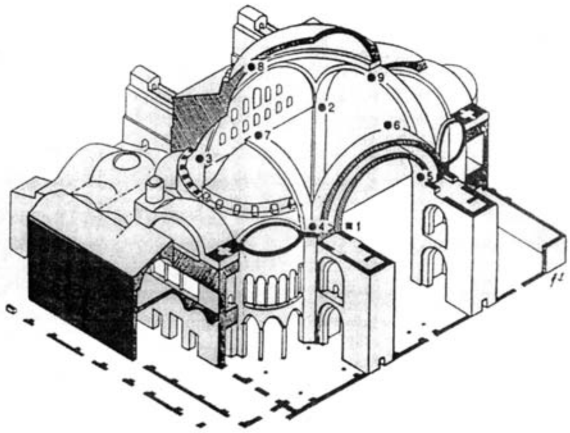
ΔΗΜΟΣΙΕΥΣΗ No 67

RAPHAEL - COMARECH
R99/II.2.a.11/GR-99/SI2.81089

COMPATIBLE MATERIALS RECOMMENDATIONS FOR THE PRESERVATION OF EUROPEAN CULTURAL HERITAGE

PACT 59 2000

Revue du groupe européen d'études pour les techniques physiques, chimiques, biologiques et mathématiques appliquées à l'archeologie - Conseil de l'Europe



Scientific Editors: A. Moropoulou, G. Biscontin, J. Delgado Rodrigues, M. Erdik

In the memory of the late and regretted Manthos Zaphiropoulos

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Publiced by:
ACCOCIATION OF CIVIL ENGINEERS OF GREECE

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MARIOLAKOS, I., FOUNTOULIS, I. & ANDREADAKIS, M., (2000). – Engineering Geological problems caused by human interference on monuments that influence their seismic behaviour. In RAPHAEL programme – COMARECH, *"Compatible materials and techniques for earthquake and monuments protection"*, p. 53-63, Istanbul, October 2000.

RAPHAEL – KOMARECH
R99/II.2.a.11/GR-99/SI2.81089
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PACT 59 2000 pp53-63
PUBLISHED BY: ASSOCIATION OF CIVIL ENGINEERS OF GREECE

ENGINEERING GEOLOGICAL PROBLEMS CAUSED BY HUMAN INTERFERENCE ON MONUMENTS THAT INFLUENCE THEIR SEISMIC BEHAVIOUR (FOUR CASE STUDIES)

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ABSTRACT

Preservation of historical monuments in tectonically active areas of Greece is difficult because of the often particularly unfavourable geological, tectonic, morphological, hydrogeological or climatological conditions. As a result, human takes measures to protect the monuments, or restore them after a natural disaster. However, the cases where human impact proves hazardous or even disastrous are rather common. In the present paper, three case studies where human impact caused geotechnical problems and one case of inevitable natural disaster are juxtaposed.

1. INTRODUCTION

It is well known that Greece, which from geological point of view consists the so called Hellenic Arc, from tectonic and seismological point of view, is one of the most active areas of the world, and for sure, the most active in Europe.
A lot of active faults cross the whole country. In some areas, the density of the active faults is very high, e.g. the area of the Isthmus of Corinthos.
At the same time, it is true that because of this activity, the so-called relief energy in many areas (high mountains, deep valleys, canyons etc) is very high.
Active faults, high relief energy, lithology and tectonic discontinuities are crucial factors for the behaviour of the buildings and therefore of the monuments.

2. THE MONASTERY OF ASSUMPTION IN PLAGIA (ZERMA) (KONITSA, IOANNINA, GREECE)

2.1. History

The monastery was originally built in the 17th century AD (Figure 1), and an overhaul took place in the 1810-1820s. In the 1920s large support walls were built on the northern, southern and western side (Figure 2). By the year 1947 the temple and the cells were burnt down by a conflagration. In the 1977, a second overhaul took place, but the problems of stability have never been stopped.

Figure 1: The temple of the Monastery of Zerma and the surrounding collapsed cells.

Figure 2: The detachment of the thick supporting wall from the wall of the temple on the north side of the temple

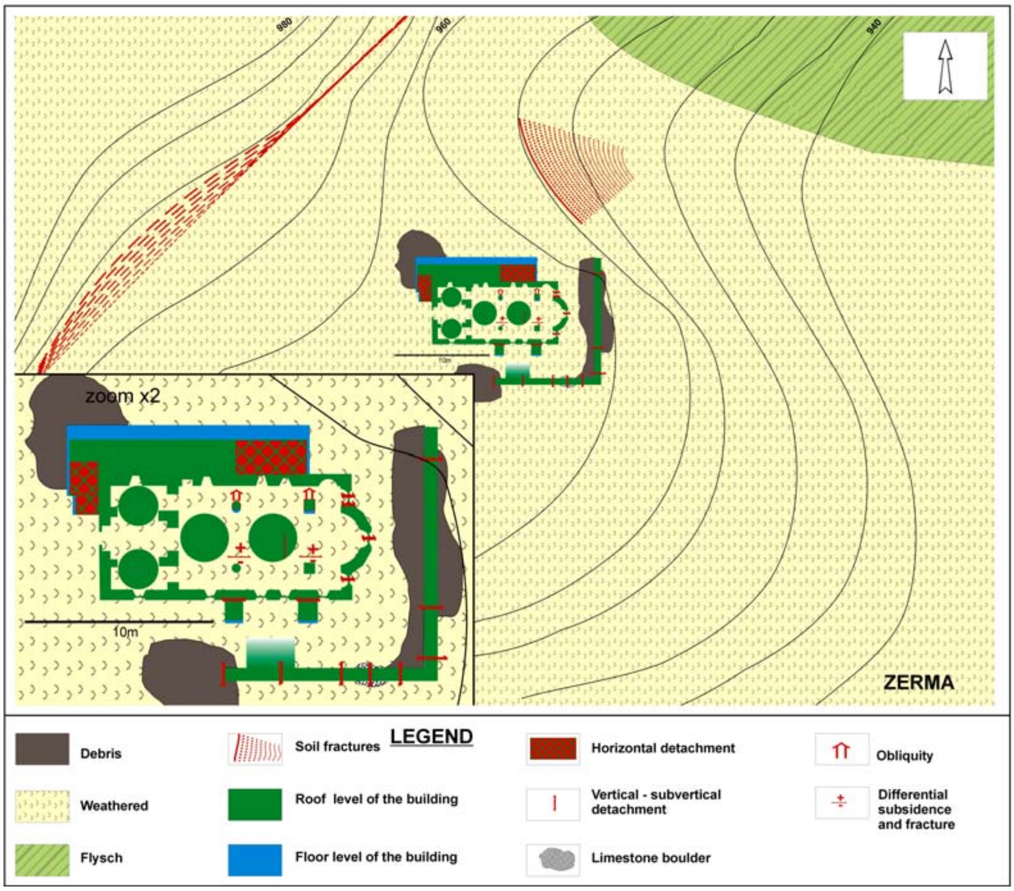

Figure 3: Sketch map of the monument in Zerma and the surrounding area.

2.2. Present situation

A differential subsidence is taking place also around and inside the temple. As a result, a tilting of the columns is observed, as well as expanding fractures, especially on the eastern wall of the temple, and on the outer walls of the collapsed cells. The walls and the structural elements of the temple have started to separate (Figures 2, 3).

2.3. Basement

Alpine rocks, mainly of the flysch group constitute the rock basement of the area, while limestone and sandstone intercalations are common. These formations have a high dip angle, and their bedding is parallel to the slope. The condition of the soil is rather unfavourable for the stability of the monument, once the earth material on the ground surface has high sensitivity, fluctuant compressibility, high erodibility, fluctuant water permeability and high potential of subsidence – expansion.

2.4. Mechanism

Earth creep on the ground surface is taking place, but slides occurring on the slopes indicate a deeper phenomenon. The subsurface water is restricted in the calcareous and/or coarse materials beds and lubricate the surfaces between the alternating lithologies of the flysch. The cohesion and viscosity of the soil are reduced and the alternating beds are sliding slowly along the surfaces.

2.5. Human impact

Amounts of water are artificially drawn from a spring uphill to the surroundings of the monastery to create a fountain, charging the loose eroded ground and actually worsening the geotechnical features. The large supporting walls built in the 1920s, instead of supporting the declining walls of the temple, they have actually added a great weight to the sides, thus dragging them downwards, and facilitating soil compaction and creep.

2.6. Proposals

Drainage of the surface water, away from the surrounding area is proposed, in combination with removal of the additional weight of the thick supporting walls. Also, bushing should be done downhill from the monument, and the situation – water table level and any vertical and horizontal movements – should be monitored.

3. THE TEMPLE OF AGIA PARASKEVI IN PALEOSELLI (KONITSA, IOANNINA, GREECE)

3.1. History

The temple was originally built in 1864, replacing an older smaller temple to cover the needs of the growing population of the local community (Figure 4). A wooden framework of joined columns and pillars form the infrastructure of the temple, supporting the 50-60 cm thick stone-brick walls. Geotechnical instability was observed by the time of the completion of the building, and the building never seemed to be influenced by seismic events, such as the latest earthquakes in the area of Konitsa. Extreme weather conditions such as intense rainfall or snowfall, however, have aggravated the situation. The posterior added shed at the southern entrance of the temple collapsed and was recently reconstructed.

Figure 4: The deformation of the shape of the temple in Paleoselli is quite impressive, once no fractures have been observed on the walls.

Figure 5:The northern side of the temple. The seepage is obvious, as well as the tilt of the shape.

3.2. Present situation

A rather impressive deformation of the temple has taken place, with differential subsidence inside the temple and tilting of columns both increasing from the northwest corner to the southeast corner. However, no fractures have been observed on the walls and no detachments at the joints of the structural elements, while the shape of the temple resembles a distorted matchbox (Figures 4, 5).

3.3. Basement

The basement is constituted of alpine rocks, and specifically sandstone and mudstone alternations of the flysch formation. The dip of these formations is high, and the bedding is homothetic to the slope. A strike slip fault zone trends throughout the area, fracturing the alpine formations. On the surface, an accumulation of earth material is located at the site of the temple, as a result of an old landslide, connected to the dip of the strata and the fault zone. The earth material shows high sensitivity, fluctuant compressibility, high erodibility, fluctuant water permeability and high potential of subsidence – expansion. Also, seepage is observed at the northwest corner right outside the temple, and a large age-old plane tree is growing a few meters downhill from the southeast corner.

3.4. Mechanism

There seems to be a mechanism of differential subsidence, directly connected to the differential saturation of the soil. The spatial differences of saturation created different plasticity and compressibility conditions, which, combined with the heavy load of the building, triggered differential subsidence. Thus, the northeast area is supersaturated, while the southeast area is undersaturated, because of the interruption of the subsurface water drainage by the construction, and the absorption of large amount of underground water by the sycamore tree. No fractures have damaged the walls, because of the excellent framework with joints of the pillars and the walls with metallic elements and beams.

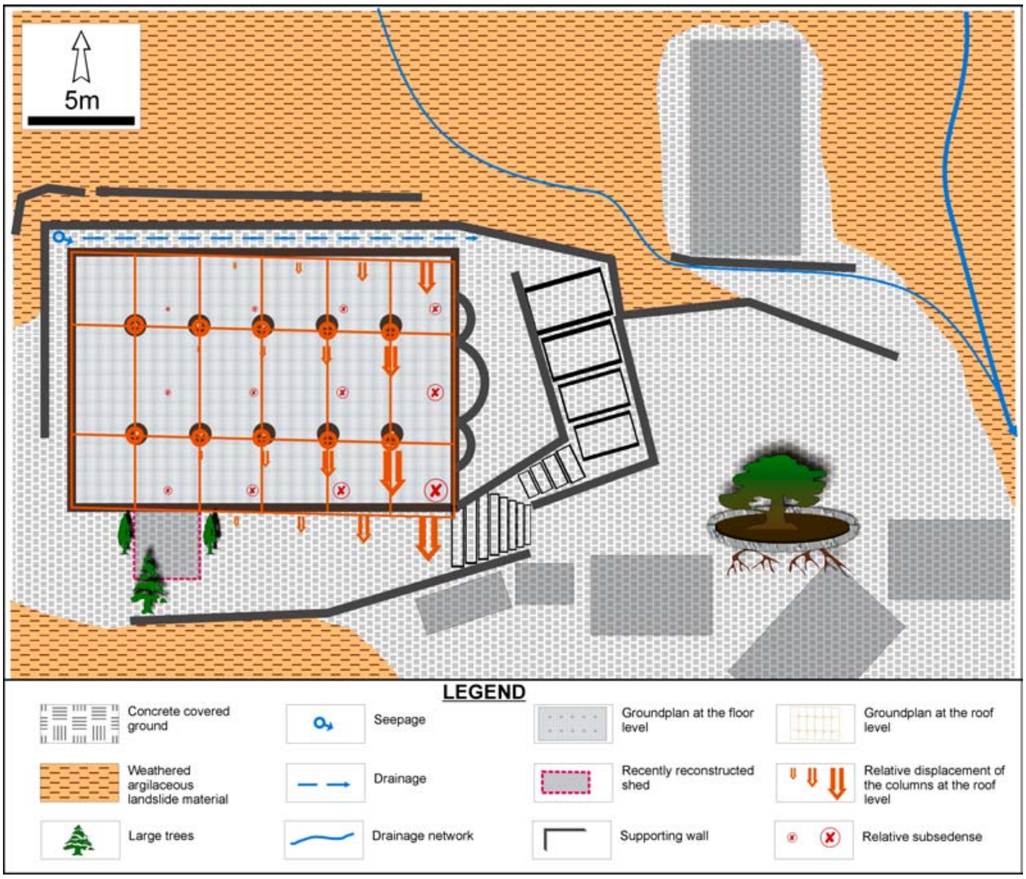

Figure 6: Sketch map of the monument in Paleoselli and the surrounding area.

3.5. Human impact

The large excavation and foundation of the temple interrupted the underground water drainage, like an underground barrier. The construction of the temple loaded the loose fine-grain landslide material with weight exceeding its strength. The surrounding area is concrete-covered, and does not permit the counterbalancing of the underground water imbalance, by the surface water.

3.6. Proposals

Surveillance of the evolution of the deformation of the temple is proposed, in combination with gradual drainage of the underground water uphill.

4. THE MONASTERY OF BIRTH OF VIRGIN MARY IN DRAMESIOI (DODONI, IOANNINA, GREECE)

4.1. History

The area is on the northeast side of the Tomaros mountain in Epirus, near Dodoni area. The monastery was built in the 16^{th} century AD. Later on, a steeple was added, and in the 20^{th} century, a new wing and an external shed were constructed around the older building. The roof of the temple was recently reconstructed, and there seems to be a major influence by the weather conditions, that are quite unfavourable in the area.

Figure 7: Creep phenomena outside the temple (east-northeast).

Figure 8: The entrance of the temple (north side). The fracture at the top of the span is due to subsidence on the left (northeast corner).

4.2. Present situation

Subsidence is observed at the northeast corner of the shed and steeple, as well as Expanding fractures on walls of the added wing, and the surrounding stone fence along the perimeter. Creep phenomena are also obvious on the slopes (Figures 7, 8).

4.3. Basement

Alpine rocks constitute the basement, that is, sandstone and mudstone alternations of the flysch, covered by glacial deposits and lanslide eroded material. A large scale thrust and parallel faults trend NW-SE uphill throughout the area. Stream incision is very characteristic, and a fluctuating water table level is developed within the deposits.

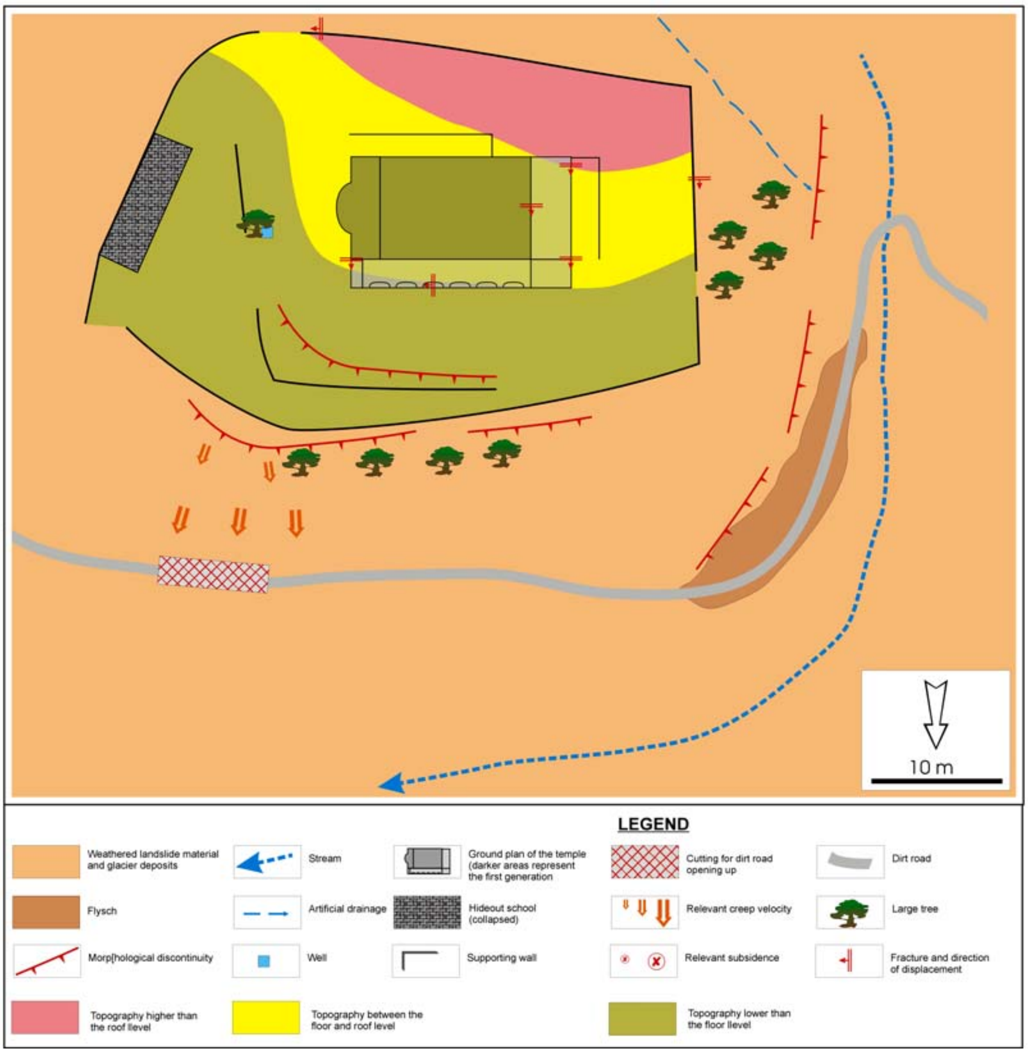

Figure 9: Sketch map of the monument in Dramesioi and the surrounding area.

4.4. Mechanism

The whole area suffers from landslide and creep phenomena, deep stream incision and extremely erosional conditions, due to loose lithology, with both coarse and fine grained material in alternations and lenses, high slope angle, lateral underwater charge from karstic limestone uphill, relatively impermeable basement, which the loose formations are easy to slide over and extreme weather conditions in winter, including periodical snow and frost cover, rainfall and large amounts of drainage. It is worth mentioning that the elder (original) part of the building had not presented any problems before the additional constructions, and that the creep phenomena seem to be accelerating after the cutting of a downhill slope for opening up of a dirt road (Figure 9).

4.5. Human impact

The addition of the new wing and the excavation for the opening of the road without any supporting of the cut slope, have accelerated the creep phenomena and expose the temple to a hazard that had not existed before.

4.6. Proposals

Light supporting wall (with drainage) at the recent cut of the road and bushing on the slope are proposed to protect the foot of the slope that supports the monument. There should be peripheral drainage around the perimeter, and instrumentation for the monitoring of the creep phenomena and the water table level should be established.

5. THE MONASTERY OF DAFNI (ATHENS, ATTICA, GREECE)

5.1. History

The monastery is sited in a neogene tectonic graben between the mountains Egaleo and Korydallos, at the west side of the basin of Athens (Figure 12). The temple was built in 11th century AD, replacing an older church. Large-scale damages are reported in the 13th century, and an overhaul took place in the 14th century (Figure 10). Extended damages occurred during the latest Athens earthquake (September 7th, 1999).

Figure 10: The temple of Assumption.

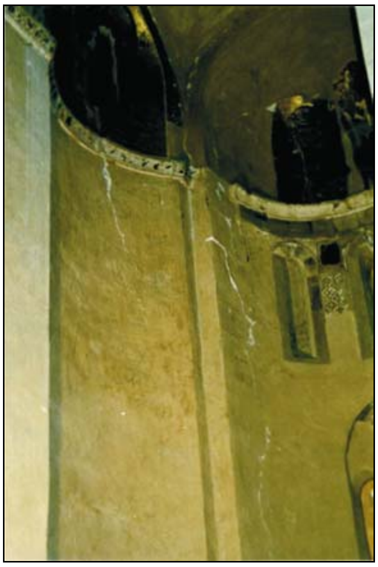

Figure 11: Fractures within the temple.

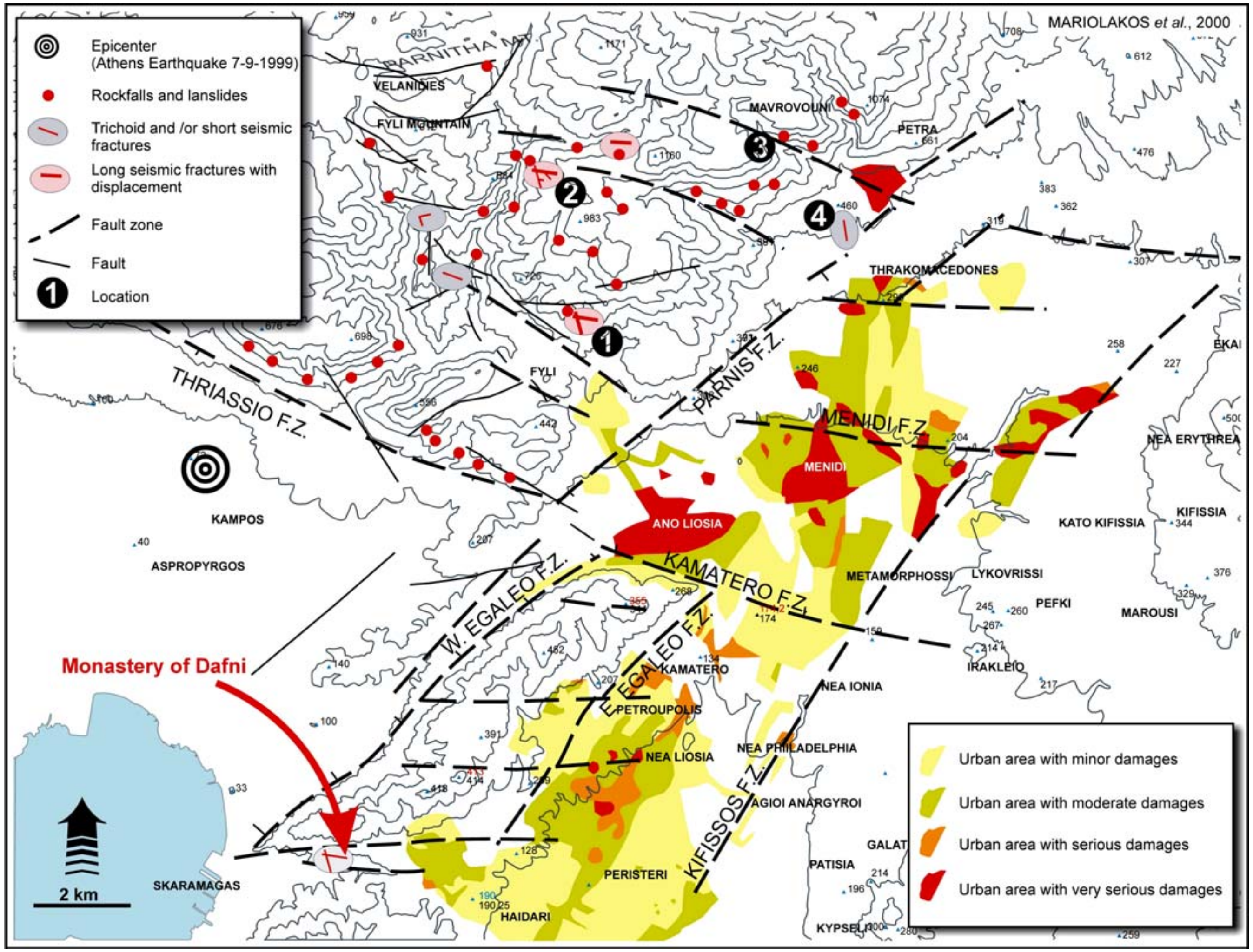

Figure 12: The broader area of Athens affected by the earthquake of Athens (September 7th, 1999) and the site of the Monastery of Dafni.

5.2. Present situation

Fractures in the nave are observed throughout the temple, especially at the higher parts (Figure 11). A large - scale strike slip fracture is developing outside the surrounding wall along several tens of metres. The surrounding wall has partially collapsed.

5.3. Basement

The monastery is sited 150 metres away from the E-W trending marginal fault between the alpine Mesozoic limestone and the post- alpine deposits. The basement consists of post alpine formations, that is, recent continental deposits of small thickness and lacustrine marls of the Upper Miocene, which form flat morphology at the site.

5.4. Mechanism

It is worth mentioning that no damages have been connected with either morphological or climatic conditions. The monastery is founded on a flat surface, no stream incision or high groundwater table is involved and after the overhaul in the 14th century, no geotechnical instability had been observed. Weather conditions are not considered unfavourable – the climate of Attica is known as one of the mildest in the world. In addition, No human intervention has affected the greater area of the monastery.

All damages occurred during the earthquake, and they are connected with seismic fractures on the ground, or the extensions of these fractures. The damages are due to the presence of the marginal fault of the graben, along which seismic energy is very high.

6. CONCLUSIONS

All four sites are located in tectonically active areas. The three first sites (in Epirus) are located in areas of high relief energy. The geotechnical conditions were not favourable from the time of foundation, but the constructions of the first generation have sustained weathering and geodynamic phenomena for several centuries without critical damages. Human impact, in the form of additional constructions, disturbance of surface and ground water circulation and slope cuts, has generated faster evolution of creep or landslide phenomena setting the constructions in hazard. Restoration of the monuments can only be successful if it includes restoration of the original constructions and the original geotechnical conditions. This is the only method to save the monuments and, all other methods unfortunately lead to the destruction of the monument in the long run. In addition, the human impact influences the behaviour of the construction against earthquakes, e.g. the rise of the groundwater table, may be the main cause for liquefaction phenomena connected with earthquakes.

At the site of Dafni, no human intervention triggered the problems. Instead, it was clearly a matter of distribution of the seismic energy along the fault zone

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