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Reducing Earthquake Losses in the Extended Mediterranean Region

UNESCO-RELEMR Workshop

28 February - 3 March 2011

Cyprus Geological Survey Department - GSD
Nicosia - Cyprus

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UNESCO-RELEMR**

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Foreword

The International Workshop on Seismicity and Earthquake Engineering in the Extended Mediterranean Region is held in Nicosia, Cyprus, on 28 February – 3 March 2011. The Workshop is an activity of the programme on Reduction of Earthquake Losses in the Extended Mediterranean Region (RELEMR). The invitation was open to the participants in the workshop to make contributions which will be included in the programme. The sessions of the workshop will discuss essentially RELEMR data exchange and the results in this area from past work. The appropriateness of the data exchange format and their analysis will be reviewed.

This brochure contains a compilation of abstracts of presentations which were made available prior to the workshop. It is hoped that it will serve as a good basis for the proceedings of the workshop. We express appreciation to the authors of these abstracts.

The content of this brochure does not necessarily reflect the views of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Paris, 11 February 2011

Badaoui Rouhban
Director
Section for Disaster Reduction
UNESCO, Paris

International Workshop on
Seismicity and Earthquake Engineering in the Extended Mediterranean Region

Nicosia, Cyprus
28 February – 3 March 2011

Preliminary Program

Sunday, 27 February 2011

Participants arrive in Nicosia

Monday, 28 February 2011

09:00 – 09:30 Registration

Opening Ceremony

09:30 – 10:30 Opening Ceremony, Chair: Dr. Eleni Georgiou Morisseau
Dr. Eleni Georgiou Morisseau, Director, Geological Survey Department
Officials of the Cyprus Government
Dr. Michael Foose, USGS
Dr. Badaoui Rouhban, UNESCO

10:30 – 11:00 Coffee/tea break

11:00 – 11:15 Logistical announcements

First Session

11:15 – 13:00 Keynote Presentation: Chair: Badaoui Rouhban

Keynote Presentation

11:15 – 11:40 Stelios Nicolaides
Contribution of the Cyprus Geological Survey Department to the reduction of earthquake risk in Cyprus

Contributed Papers

11:40 – 12:00 Christis Chrysostomou
Seismic Vulnerability and Strengthening of Existing Privately Owned Buildings: The Limassol case-study

12:00 – 12:20 Haydar Al-Shukri
Paleoseismology Study Using Near Surface Geophysics and Sand Blows

12:20 – 13:00 *to be determined*

13:00 – 14:30 Lunch

Second Session

14:30 – 16:00 Contributed Papers: Chair: Michael Foose

14:30 – 14:50 Yefim Gitteman
Controlled large-scale Explosion Sources for Infrasound Calibration of International Monitoring System

14:50 – 13:10 Jalal Al-Dabbeek
Earthquake Risk Reduction "The Degree of Awareness of Seismic Risk among Palestinian Engineers"

13:10 – 16:00 *to be determined*

16:00 – 16:30 Coffee/tea break

Third Session

16:30 – 18:00 RELEMR data exchange website: Co-chairs: Niyazi Türkelli, Keith Nakanishi, Rengin Gok
Results from the pre-meeting RELEMR data exchange will be discussed and suggestions made. Topics of particular interest include appropriateness of the data exchange format, ease of uploading/downloading of data, and output of analysis results. Presentation of analyses will also be made.

Tuesday, 1 March 2011

Fourth Session

09:00 – 13:00 Special Session on Tsunamis in the Mediterranean Sea and the Persian Gulf, Chair: Stelios Nicolaides

Keynote Presentations

09:00 – 09:30 Mohammad Mokhtari
Tsunami history and potential for future events in the Makran Region and their effect on the Persian Gulf

09:30– 10:00 Gerasimos Papadopoulos
Tsunami history in the Mediterranean Region and actions for risk mitigation

10:00– 10:30 Masahiro Yamamoto
Establishment of a sustainable and effective Tsunami Warning System

10:30 – 11:00 Coffee/tea break

Fifth Session

11:00 – 13:00 Contributed Papers, Chair: Mohamed El Zahaby

11:00 – 11:20 George Georgiou, Andrew M Clark, George Zodiatis, Dan Hayes, Tom Eleftheriou, Dimitris Glekas
Tsunami Warning and Early Response system for Cyprus – (TWERC)

11:20 – 11:40 Alexander Sursock (No Abstract)
551 A.D. earthquake and tsunami event

11:40 – 12:00 Öcal Necmioğlu
Establishing a Tsunami Warning System for Eastern Mediterranean and its Connected Seas: KOERI Contribution

12:00 – 12:20 Rami Hofstetter
Crustal structure of the Dead Sea basin from local earthquake tomography

12:20 – 13:00 *to be determined*

13:00 – 14:00 Lunch

Sixth Session

14:00 – 16:00 Contributed Papers: Chair: Avi Shapira

14:00 – 14:20 *Mohamed Hamdache*
Preliminary Analysis of the Mean and Average scenario at the main cities of Northern Algeria.

14:20 – 14:40 Jalal Al-Dabbeek
Assessment of Seismic Site Effect for Rawabi First Palestinian Planned City

14:40 – 15:00 M. J. Jiménez
Modelling local sediment structure in the Vega Baja region (SE-Spain) for the generation of earthquake scenarios

15:00 – 15:20 Najla Bouden Romdhane
Seismic hazard assessment for Tunis urban area: uncertainties investigation and treatment using logic tree approach for risk model sensitivity

15:20 – 15:40 Adnan Khasawneh
Seismic Risk Assessment for Aqaba

15:40 – 16:00 *to be determined*

16:00 – 16:30 Coffee/tea break

Seventh Session

16:30 – 18:00 Contributed Papers: Chair: Hanan Al-Nimry

16:30 – 16:50 Marina Gorstein
Seismic hazard assessment using seismological survey for the Check Post interchange bridges, Haifa, Israel.

16:50 – 17:10 Alexander Sursock (No Abstract)
Bathymetry in Lebanon

17:10 – 17:30 Mohsen Ghafory-Ashtiany
M6.5 Strong Ground Motion Data Base Scenario

17:30 – 17:50 Nasser Laouami
Strong-motion networks in Algeria and their efficient use in the derivation of regional ground-motion predictive models

17:50 – 18:10 Sebastiano D'Amico
Predictions of Ground-Motion Parmeters Based on Weak Motion Data

20:00 - Workshop dinner hosted by the Geological Survey Department

Wednesday, 2 March 2011

09:00 – 18:00 Fieldtrip: Neotectonic Activity in Cyprus
Field trip leaders: Efthymios Tsiolakis, Stelios Nicolaides

The field trip will illustrate the significant evidence of neotectonic activity in the southern part of the Island. This includes active faults, reverse stratigraphy, folding, and active fault escarpments. We will start from Nicosia and have our first stop near the village of Kiti (Larnaca District) where we will have the opportunity to see an active fault. We will then go to Yermasogia Dam (Limassol District) to see a fault escarpment in the southernmost segment of the Yerasa Fault Zone. Our third stop will be at Pissouri (half way between Limassol and Pafos) where we will see nicely exposed faulted and folded Plio-Pleistocene sediments and some gravity faults. Lastly, we will have the opportunity to see an active reverse fault with associated folding near Petra tou Romiou. Lunch will be at the Petra tou Romiou Restaurant, followed by a visit at the archaeological site of ancient Curium (Kourion) on the south-western coast of Cyprus.

Thursday, 3 March 2011

Eighth Session

09:00 – 10:30 CTBTO supporting activities in RELEMR: Chair: Rengin Gok

- CTBTO introduction to regional capacity building, NDC operations, and advantages of CTBTO cooperation to regional network operators.
- Infrasound experiment and the need for data from regional stations (John Coyne)
- Role of RELEMR's regional seismic activities in support of the CTBT Regional data exchange.
- Seismic research using regional data

10:30 – 11:00 Coffee/tea break

11:00 – 12:40 CTBTO supporting activities in RELEMR (Continued): Chair: Rengin Gok

Contributed Papers

12:40 – 13:00 Ocal Necmioglu
Scientific Activities of Turkish National Data Center

13:00 – 14:00 Lunch

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<u>Ninth Session</u>

14:00 – 16:00 ***Earthquake Model of the Middle East Region (EMME)***
Chair: Djillali Benouar
Presentation of the program Earthquake Model of the Middle East Region (EMME) which aims at the assessment of seismic hazard, the associated risk in terms of structural damages, casualties and economic losses and also at the evaluation of the effects of relevant mitigation measures in the Middle East region in concert with the aims and tools of the Global Earthquake Model (GEM). The EMME will encompass several modules such as the Seismic Hazard Module, Risk Module, Socio- Economic Loss Module and the development of an IT infrastructure or platform for the integration and application of modules under consideration. The methodologies and software developments within the context of EMME will be compatible with GEM in order to enable the integration process. As such, a comprehensive interaction between the two projects is foreseen.

Contributed Papers

14:00 – 14:20 Cuneyt Tuzun
Introduction to the EMME project

14: 20 – 14:40Mohsen Ashtiany
The Mashhad City Scenario

14:40 – 15:00 Nicholas Kyriakides (No Abstract)
Cyprus Building Inventory and its Vulnerability

15:20 – 15:40 Hanan Al-Nimry (No Abstract)
To be announced

15:40 – 16:00 Jose Feghali (No Abstract)
To be announced

16:00 – 16:30 Coffee/tea break

<u>Closing session</u>

16:30 – 17:30 Closing session

Friday, 4 March 2011

Depart Cyprus

Contribution of the Cyprus Geological Survey Department to the Reduction of Earthquake Risk in Cyprus

Nicolaides, Stelios

Geological Survey Department, 1415 Nicosia, Cyprus

The tectonic framework of the Eastern Mediterranean and the Middle East region is dominated by the collision of the Arabian and African plates with that of Eurasia (McKenzie, 1970). In this geodynamic context, Cyprus is located near the triple junction of the African, Arabian and Eurasian Plates (Papazachos and Papaioannou, 1999) and as a result it has a long history of earthquakes and tsunami activity that affected the island, as noted in written, archaeological and geological records. Because the occurrence of damaging earthquakes can have a potentially significant economic and social impact on the island, the Geological Survey Department (GSD) initiated and participated in a number of studies, over the last two decades, concerning the development of an assessment of the nature of the seismic hazard on Cyprus and the evaluation of the future economic effects associated with earthquake occurrence. The aim of this paper is to present these studies, which include microseismic, microzonation, neotectonic and tsunami hazard assessments.

The microseismicity of the island has been studied under several surveys from 1993 to 1998 in collaboration with the University of Hamburg, in order to delineate the active faults on Cyprus. Three-component seismic stations were deployed in different areas and both the onshore and offshore seismicity was observed for a total of 690 days (Makris *et al.*, 2000). More than 1700 microearthquakes were recorded and analyzed. The studies showed that the epicentral distribution was concentrated along major NNW-SSE trending faults in the western part of the island, which are strongly affected by the convergence of the oceanic lithosphere of the Herodotus abyssal plain to the west with the continental crust and lithosphere of the Cyprian Arc to the east.

Microzonation studies were initiated by the GSD and conducted in collaboration with international experts in the fields of geology, geophysics and seismology from France, Germany, Greece, U.K., U.S.A. and Venezuela. The studies covered the urban areas of the cities of Larnaca (1997), Limassol (2000), Nicosia (2004) and Pafos (2005) and included geological and geophysical investigations, evaluation of the earthquake ground motion amplification, determination of expected future earthquake ground shaking, as well as evaluation of future possible economic losses resulting from earthquakes.

Following district-specific neotectonic surveys for the needs of the microzonation studies (Soulas, 2002), a project on active tectonics in Cyprus was concluded in 2005 in collaboration with French and Armenian experts, with the aim of determining and analyzing the tectonic structures that can produce future significant earthquakes, as well as giving the seismotectonic parameters of these structures for seismic risk mitigation. Based on analysis and morphostructural interpretation of aerial photographs and satellite images, as well as detailed neotectonic field investigations, the study has identified and mapped Quaternary faults and defined the main seismotectonic and geometrical characteristics of these faults or fault systems (GEOTER, 2005).

Historically, tsunamis have affected the Mediterranean region and in particular the Eastern Mediterranean (Altinok and Ersoy, 2000; Papadopoulos, 2001; Fokaefs and Papadopoulos, 2007; Salamon *et al.*, 2007). The GSD conducted in 2004 a preliminary assessment of tsunami hazard in collaboration with Oregon State University. Existing archaeological and geological records were compiled and interpreted to indicate that every part of the shore of Cyprus has been inundated by tsunamis. Following a reconnaissance geomorphological field study that covered the entire coastline of the island, the widespread deposition and erosion of tsunami features all around Cyprus were recognized and documented (Noller *et al.,* 2005). Geomorphological features indicative of tsunami evidence (Whelan and Kelletat, 2002) include large boulders at elevations of a few meters above sea level, soil distribution with slopes barren of soil, inverted boulders, oriented large boulders of tens of meters from the shoreline, as well as boulders originating from (at or below) sea level stacked in an imbricate manner. Furthermore, this preliminary study recommended the initiation of an intensive field study to characterize the hazard of tsunamis, since they appear to have occurred in Cyprus relatively frequently over the past two thousand years.

Acknowledgements

I am most grateful to my colleagues at the GSD Ioannis Panayides, Senior Geologist, for kindly providing most of the slides for this presentation, Sylvana Pilidou, Seismologist, for useful discussions and contribution to the compilation of the material and Eleni Georgiou-Morisseau, Director, for granting authorization to present this material.

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Seismic Vulnerability and Strengthening of Existing Privately Owned Buildings: The Limassol case-study

Chrysostomou, Christis (1) and Kyriakides, Nicholas (2)

(1) Associate Professor Cyprus University of Technology, Limassol, Cyprus
(2) Post-doctoral Research Assistant, Cyprus University of Technology, Limassol, Cyprus

As the building stock of existing structures is aging, both in Cyprus and in a global scale, there is an increased need for the development of methodologies and tools for the assessment of these structures and the proposition of economically viable solutions for their upgrading which are based on local conditions.

In this paper the case study of the City of Limassol is presented. The building inventory and its categorization is first described, along with the selection of two representative buildings which were used in the case study. Then the seismic hazard is presented and finally the capacity and fragility curves that were developed for these two categories of buildings for selected damage levels taking into account local conditions. This project is funded by the Cyprus Research Promotion Foundation and the Structural Funds of the European Union.

Paleoseismology Study Using Near Surface Geophysics and Sand Blows

Al-Shukri, Haydar, Okba Al Kadi, Hanan Mahdi, and Martitia Tuttle

University of Arkansas at Little Rock, Little Rock, AR 72204

Intraplate seismicity in many cases is characterized by locked or dormant faults that may stay aseismic for hundreds or even thousands of years, however, features produced by such historic or prehistoric seismicity might be preserved in the soil or sediments at or near the surface. Some of these faults have the potential of producing very large earthquakes at shallow depths, which makes them of high risk but low probability. Well-known examples of such seismicity are the New Madrid Seismic Zone and the Charleston seismic zone both in the United States and the Gujarat Earthquake region in India. Observations indicate that zones of weakness, such as ancient rift systems, may act as the source region for such earthquakes. Due to the low recurrence rate, many of the surface features related to such earthquakes are disappeared or obscured due to weathering, erosion, farming, or other human activities.

Systematic procedure was developed which integrates multidiscipline techniques to produce high resolution two- and three-dimensional near surface images that are used to map subsurface disturbances usually associated with severe ground shaking. Such disturbances include sand blows, sand dikes, venting fissures, ground subsidence and elevations, and lateral spreading. The sequence of the techniques that was used in the study is: thorough examination of high-resolution satellite and aerial photographs to identify zones that might have been affected by previous earthquakes. This was followed by a reconnaissance and comprehensive fieldwork to collect preliminary data about the area in general. Such data includes surface geology, geomorphology, mapping sandy areas, subsidence and ground failure. This was followed by a detailed geophysical survey of a few of the most prominent features, such as the largest sand blows, to image their near surface morphology. The most reliable geophysical tools implemented for such studies are Ground Penetrating Radar and electrical resistivity. A high-resolution geophysics survey was conducted at a few sites to plan for trenching. Trenching results confirmed that these sites were affected by severe shaking manifested by the liquefied sand vented through dikes, vertical offsets and lateral spreading. Radiocarbon and/or OSL dating helped determine the date of the events. This was followed by a comprehensive geophysical survey for all mapped sites and the surrounding areas. Selected sites were trenched for sampling and verification. Finally, the research team was able to delineate the subsurface structural pattern related to a deep-seated fault that was active in the past. Geotechnical study indicates that this fault generated earthquake(s) of magnitude no less than 7.2.

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Earthquake Risk Reduction: "The Degree of Awareness of Seismic Risk among Palestinian Engineers"

Al-Dabbeek, Jalal (1) Ahmad, Hussein (2)

(1) Earth Sciences and Seismic Engineering Center
(2) Opinion Polls and Survey Studies Center

This study aims to uncover what knowledge and awareness Palestinian engineers have of the earthquake risk in the region. Its second purpose is to unearth what knowledge these engineers have of the various means of reducing such risk when designing buildings and infrastructures. Seismic designs are concerned with reducing the vulnerability of buildings to earthquakes. To improve the current situation work needs to be carried out in partnership with concerned institutions to lay out plans to develop the potentials of engineers and to enact legislations and proper mechanisms for implementing them. The regulations and their implementation policies will be congruent with international requirements, particularly those published within the Hyogo framework for action during the 2005-2015 period.

A special questionnaire was designed for this study in order to obtain the required data from engineers. The questionnaire included questions about the educational backgrounds of engineers and other demographic features. In addition to this it included questions related to the engineers' knowledge and awareness of the means that reduce the risks of earthquakes and his/her commitment and application of such means when designing, supervising and executing building projects.

The preliminary study shows that the majority of engineers believe that Palestine (Occupied Palestinian Territories – oPt) will be subject to earthquakes in the future. More than half of the engineers said that they did not study seismic design during their programs of university study. A small percentage of engineers said that they had participated in workshops in the domain of seismic design of buildings. Generally, the majority of respondents said that there is a pressing need to hold seminars, lectures and workshops that address seismic designs in buildings. Less than one fifth of the engineers said that they, their firms, or their ministries had received the seismic map of oPt. In addition, the majority of them said that they had not used the seismic map which was issued by The Center of Earth Sciences and Seismic Engineering at An-Najah National University.

The study also shows that less than one fifth of respondents know that the Committee of Engineering Offices issued regulations regarding the need for commitment to seismic designs. Conversely, we find that more than 75% of the respondents know that engineers and engineering firms are obliged to design seismic resistant buildings; such designs must be supervised and followed up by the concerned legal parties. The study also showed that nearly half of respondents do not know and have not dealt with the minimum requirements of seismic resistant buildings.

Controlled large-scale Explosion Sources for Infrasound Calibration of International Monitoring System

Y. Gitterman, R. Hofstetter, U. Peled, Y. Karmon, M. Kalmanovich, V. Giller, A. Shwarzburg and other collaborators

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Recently two large-scale calibration explosions were successfully conducted by the Geophysical Institute of Israel (GII) at Sayarim Military Range, Negev desert, Israel, on 24-26 January 2011. The experiment included two on-surface explosions of 10 tons and 100 tons of ANFO explosives, conducted in different time of the day. The Big Bags of ANFO explosives were assembled as a pyramid/hemisphere on the soft sediment surface, and detonated upward. Near-source high-pressures in air-shock waves were measured, and preliminary results correspond to expected peak-pressure values for these charges.

The experiment was initiated by the CTBTO, Vienna, and is performed in close cooperation of Israel, European and Middle East countries and the USA. The main goals of this Calibration Experiment is to provide fully controlled infrasound sources (the strongest since the establishment of the IMS network), jointly with extensive observations, for calibration of IMS infrasound stations, located in Europe, Middle East and Asia. The experiment is intended to contribute to the understanding of the infrasound propagation in the atmosphere, under winter conditions, when weather patterns (stratospheric winds) are different from those that prevail in summer, and thus improve IMS capabilities for monitoring nuclear tests. The infrasound signals from the 100 tons shot were observed at IMS infrasound stations in Russia, Kazakhstan and Mongolia.

In the previous on-surface explosion, of a similar yield that GII conducted at the same Sayarim site in August 2009 under summer weather conditions, clear infrasound signals were recorded at many regional and IMS stations to the West and North-West, up to a distance 3,500 km, near Paris, France.

The unique experiment of the pair of large-scale explosions in different seasons (weather patterns) demonstrated a clear favorable westward and eastward propagations, based on extensive international cooperation observations.

Tsunami in Makran Region and its Effect on the Persian Gulf

Mohammad Mokhtari

International Institute of Earthquake Engineering and Seismology

The Makran subduction which is located between the Zendan-Minab Fault System and Oranch Fault Zone in the Oman Gulf shows relatively low seismicity in comparison with the surrounding region. This zone is characterized by the subduction of the oceanic part of the Arabian plate beneath the Eurasian plate. In spite of low seismicity the Makran region has experienced some historical tsunamis. The total number of tsunami events in the Makran zones is 3, including two events of seismic origin, and one of unknown origin. The most recent tsunamigenic event was on November 1945 associated with an earthquake of magnitude 8.1. It has caused about 4000 casualties along the Makran coast effecting Iran, Pakistan, Oman and United Arab Emirate. Since then a long silence poses a potential threat of major tsunamigenic disaster for the coastal region.

Makran Subduction Zone is unique region in the world due to its geological and seismological characteristics. High sediment input of 7 km and shallow angle of dip and rate of subduction are interesting and distinctive features of this zone.

Based on 2D offshore seismic reflection data the main structural provinces and elements in the Gulf of Oman are (i) the structural elements on the northeastern part of the Arabian Plate and (ii) the Offshore Makran Accretionary Complex Elements. On the northeastern part of the Arabian Plate, five structural provinces and elements have been defined: the Musendam High, the Musendam Peneplain, the Musendam Slope, the Dibba Zone, and the Abyssal Plain (Mokhtari et al. 2008). The Zendan-Minab Fault System and the Accretionary front define the western and southern boundary of the Makran Accretionary Complex, respectively. The Oranch Fault Zone is located in the eastern side of this complex and is considered as the western boundary of the Indian Plate, while the Murray ridge system defines the offshore boundary of the Arabian and Indian plates. These seismic reflection data (covers both Persian Gulf and eastern part of Oman Gulf, PC2000 acquired by National Iranian Oil Company) on an ongoing project are being further analysis for refinement and better understanding of the structural elements and their tectonic significance. It is believed that the smaller fault system can act as superimposing (secondary) elements in strengthening the tsunami effect. Thus, in this respect a better understanding of the main structural elements and their tectonic behavior can be important. In addition the accretionary wedge development, being studied in more details and the result will be discussed in this presentation.

The tsunami threat faced by Indian Ocean countries in general and Makran region in specific consists of a tsunami from local, regional and distant sources, whose effects at any particular location are highly dependent on variations in seafloor shape between the source and the affected area. These factors make the design of an effective warning system problematic. In this regard, the tsunami hazard will be reported in terms of i) tsunami amplitudes at locations onshore in Iran (including Persian Gulf), Oman, UAE and Pakistan, and ii) the probabilities of experiencing these amplitudes. It is envisioned that this broad assessment will serve as a first step towards a systematic and comprehensive assessment of tsunami risk in the region.

In this respect the information obtained mentioned above could be used as first input for a comprehensive Tsunami Early Warning System. While a tsunami warning system is the most important tool to help mitigate the damage to life done by tsunamis, there are a few other things that can be done as well. Coastal development should be done with tsunami potential in mind. There are some simple things that can be done along coastlines that can help reduce the damage and loss of life from a tsunami. Sea walls and coastal dunes also can serve as buffers. The public needs to be educated. In the past, this may have been difficult, but given the tremendous awareness raised by the 2004 Indonesian tsunami the general public is far more likely to respond positively to the distribution of information by public signs at beaches seafronts or in the form of printed material. People who live in coastal settings should be given information on the risks of that environment.

In this presentation after discussing the Makran Subduction Zone tectonic, using seismological and seismic reflection data, its effect on tsunami generation will be elaborated and tsunami hazard assessment as key element for the early warning system will be introduced. Even though, the Persian Gulf due to its seismotectonic setting and shallow water depth could not be classified as tsunamigenic zone; but being close to Makran region is exposed to high level of Tsunami hazard, high vulnerability of its coastal environment, rapid population and industrial growth which all cause the high risk of the region to the earthquake and Tsunami. This issue will also be discussed in this presentation.

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Tsunami History in the Mediterranean Region and Actions for Risk Mitigation

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Segments of the Mediterranean Sea coasts have been struck in the past by large, destructive tsunamis generated by submarine earthquakes and volcanic eruptions, while powerful tsunamis have also been locally generated by landslides. More than 250 events with a variable degree of reliability were described from the antiquity up to the present. The recurrence interval for tsunami intensities $K \geq 4$, 5 and 6 is on the order of 12, 40 and 130 years, respectively, in the new 12-grade tsunami intensity scale of Papadopoulos-Imamura (2001). The highest tsunami potential was calculated along the Hellenic Arc and Trench (HAT) as well as in the Gulf of Corinth, Central Greece. In HAT, large and destructive earthquake-tsunami events occurred on AD 365, 1303 and 1956, which affected extensive areas in the basin of the east Mediterranean Sea. Large tsunamis were also generated by the volcanic eruptions in the Thera (Santorini) island complex, south Aegean Sea, in the 17th century BC and on AD 1650. In Corinth Gulf, destructive earthquake-tsunamis were reported on 373 BC and AD 1402, 1748 and 1817, while an aseismic but strong and damaging tsunami was described on 1963. However, infrequent but large tsunamis were recognized for the Straits of Messina, southern Italy, as well as in the Alboran Sea, and in the Levantine Sea including the Cyprean Arc. It is clear, therefore, that tsunami waves should not be neglected as a potential source of risk that threaten coastal communities of the Mediterranean Sea. Several approaches offer considerable potential to improve our understanding of the tsunami phenomena including the identification of earthquake, volcanic eruption and landslide sources and mechanisms. To improve tsunami risk assessment more work is needed to extend the event database, e.g. by identifying palaeotsunamis with geological methods and historical events from documentary sources, to simulate wave generation, propagation and coastal inundation applying advanced numerical models, and to map the components of physical and anthropogenic risk with the use of appropriate tools, e.g. GIS.

Recent events in Southeast Asia, the Indian Ocean and the Pacific Ocean have highlighted the importance of developing risk mitigation strategies that include public awareness activities, the development of tsunami warning systems (TWS) and the elaboration of specific civil protection plans across the Mediterranean region. The existing early warning technologies around the globe are capable to provide operationally useful warning for regional or transoceanic tsunamis having wave travel times of more than 1hour. However, they are incapable to warn for near-field tsunamis, with travel times of the order of 5 to 45 minutes, which is the most common case in the Mediterranean. The NEAMTWS/IOC/UNESCO system, which is in the building-up stage, is oriented to issue warnings only in regional scales. Therefore, so far no answer has been given on how to warn for near-field tsunamis. It is unrealistic to rely on a unique system for the entire Mediterranean basin. Instead, several local systems working on the basis of some joint principles but with local adjustments is the most promising solution. To achieve progress in this prospect the organization of the coordinated project NEARTWARN is proposed to involve research, technological development and pre-operational demonstration for the near-field tsunami early warning in the Mediterranean.

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Establishment of a Sustainable and Effective Tsunami Warning System

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The Mediterranean Sea is exposed to the risk of tsunamis. About 200 historical tsunamis, both minor and destructive, are recorded in the region. There is, however, no tsunami warning system presently in place in the region. Lack of tsunami warning system and preparedness would be more disastrous today than in the past, because of the recent rapid development of the coastal areas. New Tsunami Warning System, therefore, in the region is under developing; Intergovernmental Coordination Group for the North-East Atlantic, the Mediterranean and connected seas Tsunami Warning System (ICG/NEAMTWS), as an auxiliary body of UNESCO/IOC.

As tsunamis do not happen with a high frequency, they are often under-estimated as a risk. However, they are highly destructive and case high damages and losses of lives. An effective tsunami early warning system is achieved when all persons in vulnerable coastal communities are prepared and respond in a timely manner upon recognition that a potential destructive tsunami may be approaching. For this, tsunami hazards and risks must be known, and preparedness activities must be carried out beforehand so that when a warning is issued, it will motivate ordinary citizens to quickly move out of harm's way before the tsunami attacks. Tsunami warning training and community preparedness should be a part of the tsunami disaster mitigation programs that extend the early-warning systems as end-to-end systems. Good tsunami warning system also requires long-term planning and efficient management for a sustainable operation.

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Tsunami Warning and Early Response system for Cyprus – (TWERC)

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An extensive seafloor network has recently been deployed off the south coast of the Republic of Cyprus. The operational ocean observatory known as CYCOFOS (Cyprus Coastal Ocean Forecasting and Observing System) has now been expanded to accommodate a network of seismic and tsunami detection sensors. This expanded network, the Tsunami Warning and Early Response system of Cyprus (TWERC), will serve as the basis of a national asset that will support both research and industry. The potential in Cyprus for extensive onshore destruction from a seismically generated tsunami is significant, as shown by historical records and recent statistical studies. The tsunami threat is exacerbated by the relatively narrow width of the Mediterranean Sea, giving perhaps only minutes of warning (compared to hours in larger ocean basins). The region's high density of coastal population and infrastructure make a robust, real time tsunami detection and warning system particularly vital. The existing CYCOFOS buoy provides a unique platform to evaluate new methodologies and technologies since it is capable of providing both continuous two-way broadband communications, and substantial power to the seafloor. In late 2010, the TWERC network seafloor power and fiber optic communication cables was deployed approximately 80 km south of Cyprus, covering an area of approximately 20,000 sq-km. This same area has been delineated into "Lease Blocks" to accommodate offshore hydrocarbon exploration and exploitation. The TWERC cable was laid along the boundaries of these lease blocks, comprising an orthogonal "Z shaped" array. A series of seafloor "Junction Boxes" have been deployed at each intersection of these Lease Blocks (where the TWERC array takes an orthogonal turn). Thus, these Junction Boxes can serve the dual purpose of: 1) providing "plug-in' ports and power for environmental sensors and control devices for hydrocarbon activities that can service the adjacent Lease Blocks of each intersection, and 2) providing "plug in" ports for tsunami sensors (sensitive pressure sensors capable of resolving centimeters sea level excursions) and seismic sensors (ocean bottom seismometers). The deployment of these tsunami and seismic sensors is scheduled to be carried out in early 2011. The "Z shape" of the array facilitates time of arrival differentiation of both the tsunami and seismic waves. The Oceanography Centre of the University of Cyprus has also deployed a series of three shore-based coastal stations to monitor and report sea level fluctuations that are harmonized with this offshore system. The TWERC is aligned with the United Nations Scientific, Educational and Cultural Organization (UNESCO) Intergovernmental Oceanographic Commission (IOC) North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS).

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Establishing a Tsunami Warning System for Eastern Mediterranean and its Connected Seas: KOERI Contribution

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The complex nature of plate interactions and crustal deformation in an around Turkey are described with devastating earthquakes accompanied sometimes by catastrophic tsunamis. Historical Studies reveal that during the last 3000 years, the coastal and surrounding areas of Turkey have been affected by more than ninety tsunamis. 1303 AD Earthquake in the Eastern Mediterranean And the western Hellenic Arc Earthquake in 365 AD Are among the most well known tsunami sources. In Addition to earthquakes as tsunami sources, massive land movements, such as in the case of the Santorini event around 1600 BC or the Fatsa Tsunami Triggered by the Erzincan Earthquake in 1939 gives a clear indication that the entire region surrounding Turkey Is prone to tsunami. Therefore, it is evident that a Tsunami Warning System Needs to be put in place especially covering the Eastern Mediterranean, since tsunamis in the future could be even more harmful than the past events, when considering increased economic activity and the population density in the coastal zones.

To address the needs of a Tsunami Warning System, KOERI has taken the leading the national initiative for setting up a Tsunami Warning Center, Which is expected to undertake also Regional Watch Center Responsibilities under the UNESCO IOC–ICG/NEAMTWS. KOERI is responsible for the operation of the National Earthquake Monitoring Network For Turkey Consisting 108 Broadband and 22 Short period seismometers and is also in the process of enhancing its observational capabilities with the deployment of 5 Sea bottom observation systems in the Sea of Marmara, Including broadband seismometers and differential pressure meters, pressure transducer, strong-- motion sensor, hydrophone, temperature measurement device and flow meter. The Deployment phase is finalized in December 2010 and the system is fully operational. The Seismic component of the sea-bottom observation system will improve the spatial distribution of the existing seismic network in the Marmara region, especially after the integration with the land-based stations. Existing Seismological network is being improved especially in the coastal regions and bilateral agreements were concluded with several neighboring countries to exchange seismological data. A Protocol with the responsible national agency for sea level monitoring has been concluded and currently three tide-gauge stations are transmitting data to IOC Sea Level Station Monitoring Facility. In addition, KOERI is considering to set-up its own tide gauge network consisting of 10 stations. NAMI DANCE Tsunami Simulation - Visualization Code has been installed in KOERI and some of the tsunami scenarios have already been simulated. The near-future goal is to create a tsunami model database based on deterministic approaches (scenarios) and to derive tsunami model database for Turkey. KOERI Is expected to operate as the Regional Tsunami Watch Centre in 2012, providing coverage to Eastern Mediterranean, Aegean and Black Seas.

Crustal Structure of the Dead Sea Basin from Local Earthquake Tomography

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New findings of the velocity structure of the crust across the Dead Sea basin are obtained by applying tomography based on local earthquakes. In the study we use P wave travel-time of 614 earthquakes that occurred in the Dead Sea basin in the period 1983-2009. At all depths the Dead Sea basin is characterized by lower velocities relative to both eastern and western sides of the basin. There is a significant seismic activity at depths of 20 and 25 km, mainly in the center and the northern part of the basin.

At shallow depths (<15 km) there is more seismic activity on the eastern side of the basin than on the western side, and the northern basin is generally more active than the southern basin. There is an asymmetry in the in the faults that border of the Dead Sea basin. The Arava fault on the eastern side, with nearly vertical dip faulting, appears to be a clear boundary at all depths down to about 20 km. The depth extension of the Jericho fault on the western side of the basin is definitely limited to less than 15 km. At greater depths of 20 km or more the western side is partially bounded by a fault. The concentration of earthquakes in the central part of the basin at depth larger than 15 km suggests that the Dead Sea fault at those depths act as a one single fault that is located in or near the central axis of the basin.

The existence of a number of clusters or earthquakes that spread from shallow depth of a few km up to a depth of about 30 km point to several defined faults that traverse the Dead Sea basin, in example, the aftershocks sequence of the earthquake in 2004 in the northern Dead Sea basin. The prominent salt diapirs of Mt. Sodom and the Lisan peninsula are clear on-surface land marks. The seismic activity near Mt. Sodom is relatively low and occurs at shallow depths down to 10 km, and at larger depths (≥15 km) it ceases. It implies that the whole structure is relatively shallow with no wide and deeper extension. The seismic activity near and inside the Lisan peninsula extends to somewhat larger depth (~15 km), and then it ceases.

The fact that we observe earthquakes at large depths suggests that the upper and the lower crust are relatively cool, as was also suggested by earlier studies pointing to the fact that the heat flow is significantly below the global average value.

Preliminary Analysis of the Mean and Average Scenario at the Main Cities of Northern Algeria

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The recent seismic activity in northern Algeria, especially in the last 50 years, is characterized by the occurrence of several damaging earthquakes. The El Asnam region suffered the most destructive and damaging earthquakes recorded in northern Algeria, namely those of September *9*, *1954* (M_S *6.8*) and October *10, 1980* (*Mw 7.3*). The most significant and recent event was the May *21, 2003* (M_w *6.9*) Zemmouri earthquake, located at around 50 km northeast of Algiers. In this context, the interest of the scientific community regarding seismology and seismotectonics has greatly increased in Algeria, especially in the fields related to the seismic risk assessment of urban seismic areas and its possible reduction. We focus on the probabilistic seismic hazard in terms of PGA with 10% probability of exceedance in 50 years, which generally forms the basis for the seismic design provision of National Building Code. In this study, we disaggregate the probabilistic seismic hazard results in terms of magnitude, distance and azimuth, at several cities in Northern Algeria, to help understand the relative contributions of the different seismic focuses. Based on these results, we computed the so-called control earthquake, that is, the most contributing earthquake to seismic hazard in a certain location from a probabilistic point of view. The calculation has been performed for all main cities in northern Algeria, corresponding to the so-called 2D hazard deaggregation technique, which allows us to derive the mean and modal scenario at each site. The obtained results reveal that in some cities the hazard is completely controlled by close sources. It is the case for example in Algiers, Oran Annaba, where the dominant earthquake is produced less than 50 km away from the site., and could reaches eventually 130 and 300 km as it is the case in Tebessa, Biskra and Laghouat respectively.

The obtained results reveal also the existence of cases where sources contribute less or more to the seismic hazard, as for example in Batna, Djelfa, Bouira, Guelma and Jijel.

Afterward, the mean and modal scenarios have been used to simulate design accelerograms at each site for different soil type (rock, stiff and soft).

Keywords: Probabilistic seismic hazard, deaggregation, stochastic simulation of accelograms, Algeria.

Assessment of Seismic Site Effect for Rawabi First Palestinian Planned City

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This abstract concisely details the assessment of seismic site effect (ASSE) study that was carried out by the Earth Sciences and Seismic Engineering Center (ESSEC) at An-Najah National University for the construction of Rawabi City (First Palestinian Planned City). The aim of the study is to avoid or mitigate seismic site effect, such as: landslides, amplification and faulting systems.

Seismic refraction technique was used to investigate the city of Rawabi Site. More than 30 seismic profiles have been shot to figure out the subsurface geology and to delineate if there are cavities beneath the selected landfill site. The underground seismic models beneath the profiles show different velocities to two or three layers; the first layer represents the soil cover (weathered surface material) with maximum thickness of about 5 m overlaying a layer of sediment material (marly and clay- marly materials) or directly on consolidated carbonate materials of limestone, chalky limestone, and dolomite limestone. The underground seismic models and the time-distance results don't show clear cavities at shallow depths except slight morphological variations at bottom of marly layer which may indicate small voids. The shear wave velocity values (V_s) vary between 500 m/sec and 1500 m/sec for marly materials and hard limestone respectively. Based on thicknesses of layers and the values of V_s for each layer, the type of soil profile at the foundation levels varies between S_B and S^1_C.

The effects of local geology on ground-motion amplification and building damage were studied in Rawabi City (first stage – phase 1). Nakamura's method of microtremor analysis was applied in this investigation. The measurements showed large differences in amplification between few selected sites. Calculating the natural period of the proposed common buildings (T_b) in the studied area (buildings with 8 stories in Hai 1 – 6 and buildings with 15 stories in the city center), by using the equivalent static analysis method.

The values of T_b obtained were closed to the site dominant natural period (Ts) in few locations. On the other hand, reducing the marly stratum level in city center area by 10 – 20 meters as proposed in the master plan, will have a positive effect by reducing the seismic amplification factor measured at city center area. In other words, the city center site resonance will be avoided. For the other areas (Hai 1 – 6), the amplification factor is relatively small.

Chapter Four presents slope stability analysis to the proposed site of Rawabi City to inform safety conditions regarding slope instability and landsiding. The study models all expected cases such as excavation, building loads, backfill materials behind retaining walls and embankments and expected seismic loads. Analysis was carried out for given sections through Hai 1 and for virtual sections according to topography and local geology through the rest of the site. Results show that the stability of slopes within the site is safe. However, it is recommended to construct the buildings on the hard limestone bedrock layer and using

[1] See the soil profile table in Uniform Building Code 1997, International Building Code (IBC) , Arab Building Code 2006 or Jordanian Building Code 2005.

backfill materials according to standards. Furthermore, it is recommended to carry out slope stability analysis for real slopes within the site as they are provided by the owner.

Modelling Local Sediment Structure in the Vega Baja Region (SE-Spain) for the Generation of Earthquake Scenarios

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The “Vega Baja” region, located in the Lower Segura River Basin, is one of the Neogene-Quaternary depressions developed in the Betic Cordillera, SE of the Iberian Peninsula. The sedimentary fill is post-orogenic and its youngest materials, in general, are cohessionless or very soft silts and clays, mainly in the central part of the basin.

Earthquake activity in the region is moderate at present, although the historical record contains references to several damaging events. The strongest earthquake occurred in 1829 and it is known as the Torrevieja earthquake, with a maximum EMS-98 intensity of IX-X. Both the very recent rapid growth of urban developments together with the increase of population in the area has greatly increased seismic risk.

Geological, geotechnical, geophysical and ambient seismic noise data have been used to develop a model for the subsurface sediments in terms of resonance frequencies, shear-wave velocities and thicknesses of the sediment layers. The ambient noise horizontal-to-vertical spectral ratio HVSR technique has been applied in order to determine first, resonance frequencies and then these have been used to obtain thickness/depth relationships.

In a final step, the model obtained has been validated by a) analyzing three profiles across the region (each profile includes the information from the ambient-noise measurement sites located on a strip 1 km wide on both sides) using the main parameters of the HVSR curves (predominant frequency and maximum amplification) and those derived from the final – thickness of C-type soils, depth to rock, and average shear-wave velocity over the C-type soil-model– and b) crosschecking the resulting layering with direct observations form geotechnical boreholes. Mapping of the main characteristics of sediments has been carried out showing the variations of predominant frequency, soft sediment thickness, and depth to rock.

Seismic hazard assessment for Tunis urban area: uncertainties investigation and treatment using logic tree approach for risk model sensitivity

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Most of the international building seismic codes and regulations use response spectrum in elastic design and retrofit. It is always associated with a 475 years return period acceleration level which is evaluated through seismic hazard assessment. In this stage, Probabilistic models (PSHA) have been massively used (US-Shakemaps, GSHAP …) since A. Cornell-Mc-Guire (1968, 1976) implemented methods which help investigating hazard through attenuation laws, seismic sources and recurrence models. It is now established that PSHA is associated to different types of uncertainties. This leads to commit errors that can over or under-estimate intensity levels like last major events in last 10 years. This work treats those errors that are qualified by random and epistemic. The former concern data that can be more investigated through site collected data (b-value, magnitude of complete reporting, maximum magnitude…). The latter relates our lack of knowledge about some seismic parameters (appropriate attenuation law, seismic sources, sources depths, fault activity…). In this case, logic tree approach (Kulkarni et al,. 1984) is used through investigated data and associated errors to come out with exhaustive hazard scenarios and enough realistic weights for tree branches. Seismic risk sensitivity is then provided to measure hazards impacts (considering simplified site effects amplifications by Wald and Allen 2007 model) on direct losses for a more than 1000 buildings sample in Tunis urban area. FEMA-HAZUS software is used here through its advanced engineering building module or AEBM to give direct losses on buildings for three maintained scenarios and by damage levels.

Keywords
Seismic hazard, logic tree, epistemic and random errors, risk model, model sensitivity, FEMA-Hazus.

Seismic Risk Assessment for Aqaba city – Jordan

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Seismic risk assessment is an important step to seismic hazard reduction. Knowing the seismic risk and possible losses allows for appropriate financial planning, improve public awareness, assessment and sharing of the necessary manpower for mitigation and disaster management operations, educating the public and experts on preparedness and mitigation, and prioritization of retrofit applications .

Components of seismic risk assessment and loss estimation are: Hazard analysis; Local site effects (microzonation); Exposure information (structural inventory); Vulnerability analysis; Estimation of risk and loss.

The main objective of this study, to perform an earthquake risk assessment (ERA) for the Aqaba city. The results of the study will utilize by policy makers to set plans for the different links of the seismic risk mitigation chain.

In This study the next topics has been investigated

- Assessment of seismic hazard based on the seismo-tectonic structure, surface geology and local site conditions.
- Calculation of hazard values in the city resulting from deterministic hazard analysis, which is from scenario earthquakes.
- Inventory of buildings, lifelines and infrastructure for a selected target area within the city.
- Classification of the vulnerability of the built environment to earthquake damage for the target area.
- Realization of damage scenarios (building damage, fatalities and casualties and people left homeless).
- Development of a Disaster Risk Management Master Plan for Aqaba city
- Public dissemination of the project’s results to the public and policy makers to enable proper disaster mitigation and response planning.

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Seismic Hazard Assessment Using Seismological Survey for the Check Post Interchange Bridges, Haifa, Israel

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Seismic wave amplification in soft deposits contributes to damage and loss of life in earthquakes. Acceleration spectrum assessment requires that effect of local site geology be taken into consideration. Site investigations carried out at several thousands of sites across Israel demonstrate the efficiency of using the horizontal-to-vertical spectral ratios from ambient noise measurements to identify sites with high amplification effects, determine their resonance frequencies and construct reliable subsurface models, which are then incorporated into the process of seismic hazard assessment.

A series of ambient noise measurements and H/V spectral ratio technique were used to calculate linear and non-linear uniform hazard site-specific acceleration response spectra for the Check Post interchange bridges, located in close proximity to the possibly active Carmel fault and a few tens of kilometers from the active Dead Sea Transform fault.

M6.5 Scenario Strong Ground Motion Data Base

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Collapse of structures has been the main cause of human and economic losses in the past earthquakes. The reliable prediction of seismic collapse capacity of structures needs to perform nonlinear dynamic analysis such as IDA with a reasonable number of SGM accelerograms, which are selected based on magnitude, distance and site conditions. The Past studies have shown that characteristics of input accelerograms and signal processing of raw accelerograms have some effects on nonlinear response of structures.

In this paper the effect of SGM data processing on the nonlinear dynamic response has been studied and a guide for selection of right type of filters with correct estimation of high and low pass frequency that would result to minimum possible dispersion in nonlinear response will be given. Finally considering that occurrence of most of the devastating earthquake in Iran have magnitude of around M=6.5; a M6.5 Scenario Strong Ground Motion Data Base has been introduced that are useful for nonlinear and collapse analysis of structures has been introduced. This data base which is shown in Table 1 is composed of 70 accelerograms from 24 earthquakes (maximum of 6 records per event) that have 6<Mw<7.6, 0.1g<PGA<0.85g, 10Km<R<100Km, 175m/s2<Vs30<750m/s2, fhp<0.25Hz. The acceleration spectra of this data base is shown in Figure 1.

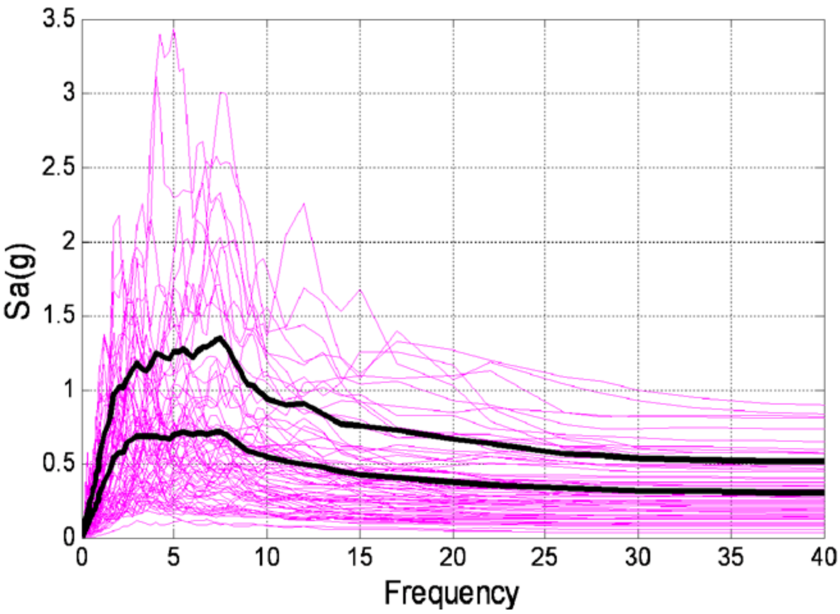

Figure 1: Acceleration Response Spectra of the 70 SGM records in M6.5 data base

Table 1: M6.5 Scenario SGM Data Base

No	Event	Year	Station	M	PGA-processed(g)	Distance(Km)	Vs30
1	Bandar-e-Abbas	1975	Bandar-e-Abas 3*	6.1	0.13	36	337
2	Tabas	1978	Boshrooyeh*	7.4	0.10	55	564
			Tabas*	7.4	0.81	54	645
3	Tularud(Gilan)	1978	Talesh*	6	0.24	15	539
4	Qaen(Khorasan(south))	1979	Khezri*	7.1	0.10	75	701
			Gonabad*	7.1	0.10	93	529
5	Golbaft	1981	Golbaf*	7	0.28	13	365
6	Manjil-Rudbar	1990	Qazvin*	7.4	0.27	94	456
			Abhar*	7.4	0.21	101	291
			Ab-bar*	7.4	0.57	41	291
7	Eslamabad(Ardebil)	1997	Kariq	6	0.57	48	589
8	Avaj	2002	Kaboodar Ahang	6.5	0.16	62	613
			Razan	6.5	0.20	35	314
9	Kajoor,Firoozababd	2004	Hasan Keyf	6.3	0.84	42	339
			Moalem Kelayeh	6.3	0.29	99	490
10	Enchehborun	2005	Agh Gala	6.1	0.12	14	341
11	Zarand	2005	Zarand	6.4	0.32	16	226
12	Erzurum	1983	Meteoroloji İstasyon	6.6	0.17	35	316
13	Adana	1998	Tarım İlçe	6.2	0.28	48	263
			Meteoroloji İstasyon	6.2	0.13	65	366
14	Kocaeli	1999	Devlet Hastanesi	7.4	0.14	81	348
			Meteoroloji İstasyon	7.4	0.37	101	282
			Marmara Araştırma Merkezi	7.4	0.12	43	701
15	Duzce	1999	Bayındırlık ve İskan	7.1	0.81	36	294
16	Bingol	2003	BAYINDIRLIK VE ISKAN MUDURLUGU	6.3	0.50	12	529
17	Northridge	1994	Beverly Hills	6.7	0.49	13	356
			Canyon country-WLost cany	6.7	0.48	27	309
18	Friuli	1976	Tolmezzo	6.5	0.34	20	425
19	San Fernando	1971	La-Hollywood Stror FF	6.6	0.18	40	316
20	Imperial Valley	1979	Delta	6.5	0.34	34	275
21	Landers	1992	Yermo Fire Station	7.3	0.24	86	354
22	Loma Prieta	1989	Hollister City Hall Annex	6.9	0.25	47	199
23	NewZealand	2010	Heathcote Valley Primary School	7	0.63	43	
24	Chi-Chi	1999	Chi-Chi-CHY101	7.6	0.40	32	259
			Chi-Chi-TCU045	7.6	0.47	76	701

Strong-motion networks in Algeria and their efficient use in the derivation of regional ground-motion predictive models

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Algeria is located on the northern edge of the African plate, which is converging with the European plate. Northern Algeria is a highly seismic area which experienced several destructive moderate-to-strong earthquakes in the past. Since the installation of the Algerian accelerographs network (335 stations), several earthquakes were recorded and constitute currently a very rich data bank. From this data bank, a strong motion catalog is established and contains information regarding the magnitude (Ms), the hypocentral distance, the site type, earthquake and stations locations …etc. Actually, the catalog contains around 1000 records ($2 < Ms < 6.9$ and $7 < Dhypo < 160$ Km). One of the most important applications was to derive an attenuation relationship for Algeria.

The considered spectral attenuation model accounts for geometrical spreading, anelastic attenuation, and geological site conditions. The regression method, introduced by joyner and Boore (1981), is a two-step inversion [Fukushima and Tanaka, 1990; Fukushima and Tanaka, 1992]. The attenuation model describes the evolution of spectral acceleration according to magnitude, hypocentrale distance, and category of the site according to the equation:

$$\mathrm{Log10}\ PSA(f) = a(f)\ M + b(f)\ d - \log10 d + C1,2\ (f)$$

Spectral attenuation laws were derived from 749 horizontal components. The datasets are mainly constituted of Algerian strong motion records (90%) homogeneously processed. In order to complete the distribution data beyond magnitude 6, a few American and European records were added, representing 10% of the datasets.

The pic ground acceleration standard deviation is around 0.34, and the residual values between observed and predicted spectral accelerations are studied and do not exhibit any bias. The inferred laws are in good agreement with classical strong motion attenuation laws as Berge Thierry et al. (2003) and Ambraseys et (2005).

Predictions of Ground-Motion Parameters Based on Weak Motion Data

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The evaluation of the expected peak ground motion caused by an earthquake is an important problem in earthquake seismology. It is particularly important for regions where strong-motion data are lacking. In this study, following a recent paper by Malagnini et al. (2010), we characterize the scaling of the ground motions obtaining results for seismic attenuation, geometrical spreading, and source parameters in different areas. Results on region-specific crustal attenuation and source scaling were used to generate stochastic simulations both for point-source and extended-fault ruptures through the computer codes: Stochastic Model SIMulation, SMSIM (Boore 1996, 2003) and Extended-Fault Model Simulation, EXSIM (Motazedian and Atkinson, 2005 and Boore, 2009). The absolute peak ground accelerations (PGA), peak ground velocities (PGV) and %5-damped Spectral Accelerations (SA) at three different frequencies, 0.3 Hz, 1.0 Hz and 3.0 Hz for several magnitude and distance ranges, as well as beyond the magnitude range of the weak-motion data set on which they are calculated. Where possible the predictions are compared with recorded strong motion data and empirical ground motion prediction equation obtained for the study region.

In this paper we focused on two recent and well recorded events: the Mw=7.6 20th September 1999 Chi-Chi earthquake (Taiwan), and the Mw=6.2 the 6th April 2009 L'Aquila earthquake (Italy) showing that our regional parameters, obtained from independent weak-motion database, may be applied for evaluation of ground motion parameters for earthquakes of magnitude up to 7.6.

Furthermore, we applied stochastic strong ground motion simulation for finite faults to estimate the spatial distribution of peak ground acceleration and velocity from the destructive 1908 Messina earthquake and the 1693 Hiblean earthquake. Computed peak ground acceleration and velocity were converted to macroseismic intensities using empirical formulas and compared to the observed intensities.

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Scientific Activities of Turkish National Data Center

Meral Özel, N., Şemin, K.O, Necmioğlu, Ö., Koçak, S., Destici, C., Teoman, U.M.

Boğaziçi University, Kandilli Observatory and Earthquake Research Institute (KOERI)

Bogazici University - Kandilli Observatory and Earthquake Research Institute (KOERI) is acting as the Turkish National Data Center (NDC) and responsible for the operation of the International Monitoring System (IMS) Primary Seismic Station (PS-43) Under Belbasi Nuclear Tests Monitoring Center for the verification of compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The NDC is sharing the responsibility with U.S. Air Force Technical Application Center (AFTAC) for the operation and maintenance of two arrays in central Anatolia.

The Belbasi array was established in 1951, as a four-element (Benioff 1051) seismic array as part of the United States Atomic Energy Detection System (USAEDS). Turkish General Staff (TGS) and U.S. Air Force Technical Application Center (AFTAC) under the Defense and Economic Cooperation Agreement (DECA) jointly operated this short period array. The Station was upgraded and several seismometers were added to array during 1951 and 1994 and the station code was changed from BSRS (Belbasi Seismic Research Station) To BRTR--PS43 Later on. PS-43 is composed of two sub-arrays (Ankara and Keskin): The medium period array with a ~40 Km radius located in Ankara and the short-period array with a ~3 Km radius located in Keskin. Each Array has abroad band element located at the middle of the circular geometry. Short Period instruments are installed at depth 30 Meters from the surface while medium and broadband instruments are installed at depth 60 Meters from surface.

On 25 May 2009, The Democratic People's Republic of Korea (DPRK) claimed that it had conducted a nuclear test. Corresponding Seismic event was recorded by IMS and IDC Released first automatic estimation of time (00:54:43 GMT), Location (41.2896°N and 129.0480°E) and the magnitude (4.52 mb) of the event in less than two hours time (USGS: 00:54:43 GMT; 41.306°N, 129.029°E; 4.7 mb) During our preliminary analysis of the 25th May 2009 DPRK event, a clear P-arrival at 01:05:47 (GMT) at BRTR SP array was observed. The result of the f-k analysis performed in Geotool software, provided by CTBTO and installed at NDC Facilities in 2008, was also indicating that the arrival belongs to the DPRK event. When comparing our f-k results (calculated at 1-2 Hz) with IDC-REB, however, it was noticed that our calculation and therefore corresponding residuals with reference to REB residuals are much better. The outcome of this analysis was communicated to CTBTO and the case story represents an example of cooperation.

Bala Earthquake occurred in central Anatolia on 20 December 2007 had produced many aftershocks that were monitored extensively by the Keskin array. We present here also the detection capability of Keskin SP array based on the analysis of the aftershock sequence. Array based waveform correlation and STA/LTA Methods are applied to the aftershock data set and detection capability results are compared both with the National Earthquake Monitoring Center (NEMC) and the Scientific and Technological Research Council of Turkey (TUBITAK) network. During 20-31 December 2007, 1.132 aftershocks within 0.8–5.0 magnitude range were detected using STA/LTA method, whereas the number of detected earthquakes was 1.401 within 0.5–5.0 magnitude range when using waveform correlation method. The results clearly indicate that array stations have much higher detection capability when compared to single stations, especially at the lower magnitude levels when using waveform correlation method.

A regional Program of GEM: Earthquake Model of Middle East (EMME)

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The number of people died in earthquakes and tsunamis worldwide in the last decade is about half a million, based on recent statistics. The majority of this life loss occurred in developing countries where population and urbanization is increasing rapidly without any major control, there by also yielding a high risk for the future. The Middle East region is located at the junction of major tectonic plates, namely the African, Arabian and Eurasian plates, resulting in very high tectonic activity. Some of the major earthquake disasters in human history occurred in the Middle East, affecting most countries in the region. Being one of the most seismically active regions of the world, Middle East, extending from Turkey to India, is also a key region in terms of urbanization, energy reserves and industrialization trend. The region under consideration involves world's most populated capitals and cities with key economical importance such as Istanbul, Baghdad, Tehran, Jeddah, Riyadh, Cairo, Kabul, Karachi and Lahore.

It is a well known fact that earthquakes cause, not only direct damage on built environment such as buildings, infrastructure or lifeline systems and result in human life and economic losses but have also secondary effects such as social and economic losses. As a consequence of the high probability of earthquake occurrence combined with high population growth, poor construction standards and practice and lack of proper mitigation strategies, Middle East represents one of the most seismically vulnerable regions worldwide.

Especially starting from 1990's, seismic risk and associated mitigation strategies have been assessed in worldwide scale through different initiatives funded and coordinated by international organizations such as United Nations and World Bank. As a result of these projects many valuable and applicable results have been obtained. As one of the latest initiatives, GEM (The Global Earthquake Model) aims at carrying former studies a step further by allowing meaningful comparisons between different regions through uniform data, methodologies, models and training. Through interactive research activities performed by researchers from different disciplines, such as engineering and geosciences, the project will provide a comprehensive and uniform evaluation of the seismic risk and associated mitigation studies.

As a consequence of the high probability of earthquake occurrence combined with high population growth, poor construction standards and practice and lack of proper mitigation strategies, Middle East represents one of the most seismically vulnerable regions worldwide. EMME (Earthquake Model of the Middle East Region) aims at the assessment of seismic hazard, the associated risk in terms of structural damages, casualties and economic losses and also at the evaluation of the effects of relevant mitigation measures in the Middle East region in concert with the aims and tools of GEM. EMME encompasses several modules such as the Seismic Hazard Module, Risk Module, Socio Economic Loss Module and the development of an IT infrastructure or platform for the integration and application of modules under consideration. The methodologies and software developments within the context of EMME will be compatible with GEM in order to enable the integration process. EMME will be a living model, rather than a static study, with a flexible, modular architecture to allow addition and updating of components and datasets, and to maintain it continuously as state of the art and in conformance with national developments and new international standards. As such, EMME will allow multiple user types to derive updated products and outputs, and keep up with changing requirements.

The users and beneficiaries of EMME will be broad, and include all those who make decisions based on seismic risk: seismic agencies, engineers and practitioners, government officials, insurance and finance industries, emergency responders, risk professionals, homeowners, investors, and the population at large. EMME is jointly directed by Eidgenössische Technische Hochschule Zürich (ETHZ) and Kandilli Observatory and Earthquake Research Institute (KOERI). A total of six work packages exist. The work packages are: Earthquake Catalog (WP1), Seismic Sources (WP2), Ground Motion Predisciton Equations (WP3), Risk Assessment (WP4), City Scenario (WP5) and Socio-Economic Impact (WP6). The institutions participating to EMME are: Boğaziçi University, Middle East Technical University and Sakarya University from Turkey, IIEES from Iran, NDMA and NED University of Engineering and Technology from Pakistan, Yarmouk University from Jordan, Cyprus University of Technology, ACNET from Georgia, SCI from Armenia, ANAS from Azerbaijan and ETHZ from Switzerland.

The second year of the EMME project will end by March 2011. By that time a complete model of seismicity and active faults will be obtained. By June 2011, the first three work packages of the project will be completed with all deliverables submitted, which will enable the computation of the seismic hazard with several models, logic tree considerations, sensitivity analyses and deaggregration. The regional building inventories and associated building taxonomies will also be compiled by June 2011, allowing for the building damage, casualty and loss calculations and socioeconomic impact measurements to be conducted within the second half-term of the project

Development of Mashhad Earthquake Risk Model

Mohsen Ghafory-Ashtiany[1] *and Engr. Hassan Tabaroie*[2]

Project Directors
[1]SP Insurance Risk Management Institute and Iranian Earthquake Engineering Association
[2]Deputy Mayor of Mashhad Municipality in Planning and Development Holy City of Mashhad, Iran

1. Summary

Reduction and Control of Seismic Risk in any given area (especially in an urban area) is a complex problem that requires integration of all reliable information and data into a systematic risk model in order to identify the exposed risk to the all components of a city. The development of the integrated earthquake risk model of the holy city of Mashhad in Iran will be the key for the implementation of an effective risk reduction program in Mashhad. For this purpose, all of the required data and investigations related to seismic risk (seismic source, seismicity, hazard, soil condition, buildings, lifeline, infrastructure, population) will be collected, updated and compiled into an integrated GIS database; as well as to update and complete the information that is needed for the risk analysis. All of the project's activities will be performed within the scope and framework of EMME-GEM project, by making maximum benefitting of GEM related tools, models and information.

The Municipality of Mashhad in cooperation with the Saman Paydar Risk Management Institute (SPRMI), Islamic Azad university-Science and Research Branch (IAU-SRC), Iranian Earthquake Engineering Association (IEEA) and Civil Research Center (CRC) will develop the MERM (Mashhad Earthquake Risk Model) as an important step toward understanding the level of risk and the vulnerable area in order to develop the action plan for earthquake risk reduction of the second important and largest touristic city of Iran, Mashhad, within the framework of National Risk Reduction Strategy of Iran.

2. Background and Motivation

Iran National Strategy for Risk Reduction calls for earthquake hazard assessment and risk and vulnerability reductions of important cities of Iran. Past years several attempts have been made in Mashhad to evaluate the city risk to natural hazard. Several studies aimed at seismic hazard studies and geotechnical investigation and Zonation have been done for area of the Holy Shrine and for the city of Mashhad, which they lack coordination and compatibility. Different city inventories have been collected which they need to be completed in a unified database system and being put in GIS format. Also attempts has been made for the disaster management response planning and preparedness, which they lack the base information.

Start of the GEM-EMME project and call for the WP5-City Scenario risk analysis, provided a good opportunity and motivation to develop the MERM using the GEM tools, methods and experiments; in order to provide a reliable and up-to-date-able assessment and information of for the city managers.

To emphasize the current situation Iran, the ultimate goals which are highly needed in Mashhad Risk Management are as follows:

- Earthquake risk reduction.
- Redevelopment, retrofitting and reconstruction of vulnerable structures, infrastructures and lifelines in urban areas.
- Development of earthquake mitigation and preparedness strategies and activities.
- Estimation of number of casualties and damages in scenario earthquakes.
- Development of basic inventories exploitable in various methods of damage assessment and quick loss estimation to be used for disaster management after strong earthquakes.

The implementation of the MERM will be the best chance for making maximum benefit of the past studies for the vulnerability. At the same time considering the high level of seismic hazard and seismic risk in Iran as well as the great amount of data and human resources, we propose to advance to a higher level as compared with other developing country the capability to estimate earthquake losses in Iran, specially the city of Mashhad considering the scenario mode. This is an important project, because Iran has suffered greatly from disastrous earthquakes during the last few decades and that such knowledge is essential for Mashhad considering its high seismic risk.

3. Objectives and Expected Impact

The main objective is to develop advanced scenario-based Earthquake Risk Model for the city of Mashhad. The risk model will be based on the scenario earthquakes derived from seismic hazard model, completed and detailed information on urban inventories of elements at risk (building stock, infrastructure, lifeline and population), buildings and lifeline fragility/vulnerability functions, vulnerability and damage assessment of the build environment and socio-economic loss estimation. The elements of the projects are:

- Development of the updated model of Mashhad Seismic Hazard and Identification of Shaking Scenario and scenario-based seismic microzonation mapping
- Development of the updated Geotechnical Hazard analysis and geotechnical microzonation map of Mashhad.
- Development of Strong Ground Motion Parameters (PGA, Design Spectra, etc.) for various earthquake scenario and soil conditions.
- Collection and Development of “elements at risk” inventories database of buildings, city lifelines, infrastructures and industrial facilities; and human and financial values as detail as possible.
- Development/Selection of required vulnerability functions appropriate for Mashhad buildings; and vulnerability evaluation of the elements at risk in a proper scale for potential level of seismic hazard in Mashhad.
- Estimation expected human and economic loss; and study of socio-economic impacts and measures to alleviate the outcome.
- Risk reduction and mitigation recommendation.
- Capacity building.

The main output of the “Mashhad Earthquake Model” can be used in the new master plan of “Mashhad Urban Development”; as well as in the earthquake risk prevention and mitigation preparedness program of activities. The main impact of this project is communication of the

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facts on expected physical and socio-economic risk of Mashhad to earthquake to the decision makers and general public; which can provide a strong basis and enforcement for the effective implementation of the risk reduction activities in Mashhad. It shows that Mashhad long-term development strategy cannot be achieved without seismic-hazard-compatible development and aseismic design and construction. It helps the people to take earthquake more serious and cooperate more in the building code implementation; and put more efforts and time toward national earthquake preparedness program.

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UNESCO - RELEMR

WORKSHOP ON SEISMICITY AND EARTHQUAKE ENGINEERING IN THE EXTENDED MEDITERRANEAN REGION

28 FEBRUARY – 3 MARCH 2011

NICOSIA, CYPRUS

Field Excursion Guide

"Neotectonic Activity in Cyprus"

Compiled by:

Stelios Nicolaides and Efthymios Tsiolakis

Cyprus Geological Survey Department

Nicosia, 2 March 2011

HEALTH, SAFETY AND THE ENVIRONMENT

Local emergency and other useful telephone numbers

Emergencies:	112 or 199 (police, fire, ambulance)
Nicosia General Hospital:	(+357) 22801400 or 1400 (information)
Nicosia Police Headquarters:	(+357) 22802020
Hilton Park Hotel:	(+357) 22695111, Fax: 22351918
Cyprus Geological Survey:	(+357) 22409213, Fax: 22316873

Field trip leaders

Efthymios Tsiolakis:	(+357) 99512703 (mobile)
Stelios Nicolaides:	(+357) 99482414 (mobile)

Health and Safety

- Please inform the field trip organizers of any relevant medical condition.
- Please do not photograph any military installations you may see.
- Stay with the group. If you become separated, stay where you are and wait to be found. Ring the field trip leaders on their mobile telephones, if possible.
- Please exercise extreme care walking along or crossing roads.
- Avoid steep faces, slippery slopes and steep cliffs.
- Wear suitable boots with a good grip and ankle support.

Environment

- All rubbish must be returned by the field group and disposed of properly.
- Only collect rock specimens for genuine scientific purposes. Where possible, collect samples from scree, otherwise take sample from inconspicuous parts of an outcrop.
- Leave the site undamaged so that other colleagues can enjoy it.
- Respect wildlife.
- Smoking: Dry vegetation makes wildfires a serious risk. Please take utmost care when extinguishing cigarettes after smoking in the field.

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An Overview of the Geology of Cyprus

Stelios Nicolaides, Ioannis Panayides and Eleni Georgiou-Morisseau

Cyprus Geological Survey Department

Cyprus is divided into four geological zones (Fig. 1): (a) the Pentadaktylos (Keryneia) Zone, (b) the Troodos Zone or Troodos Ophiolite, (c) the Mamonia Zone or Complex and (d) the Zone of the autochthonous sedimentary rocks (Geological Survey Department, 1997).

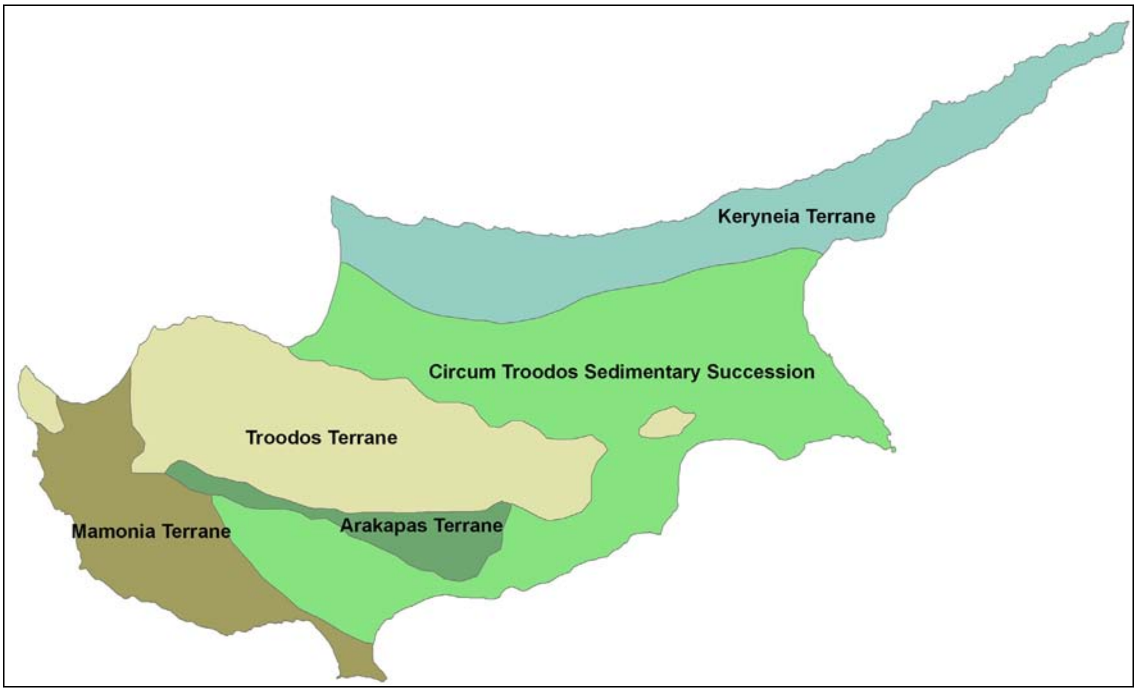

Fig. 1: The four geological zones of Cyprus.

The Pentadaktylos (Keryneia) Zone

The Pentadaktylos (Keryneia) Zone is the northern-most geological zone of Cyprus and is considered to be the southern-most portion of the Tauro-Diranide Alpine Zone. It has an arciform disposition in an east-west direction and is characterized by southward thrusting. The base of the Zone is mostly composed of a series of allochthonous massive and recrystallized limestones, dolomites and marbles of Permian-Carboniferous to Lower Cretaceous age (350-135 Ma). These are stratigraphically followed by younger autochthonous sedimentary rocks of Upper Cretaceous to Middle Miocene age (67-15 Ma), on which the older allochthonous formations have been thrust southward.

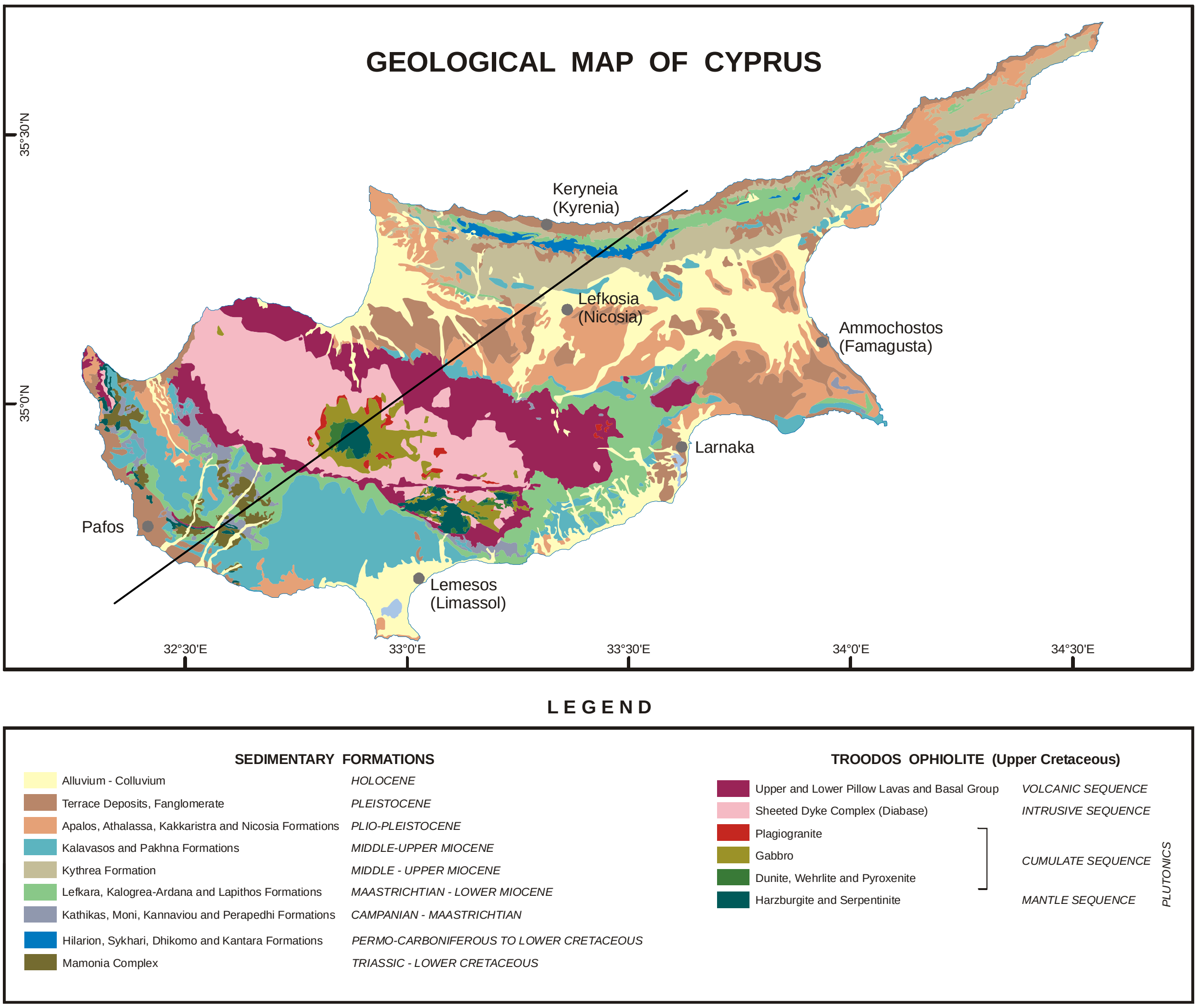

Fig. 2: Geological map of Cyprus (Geological Survey Department, 1995). Scale of map: 1: 1,800,000.

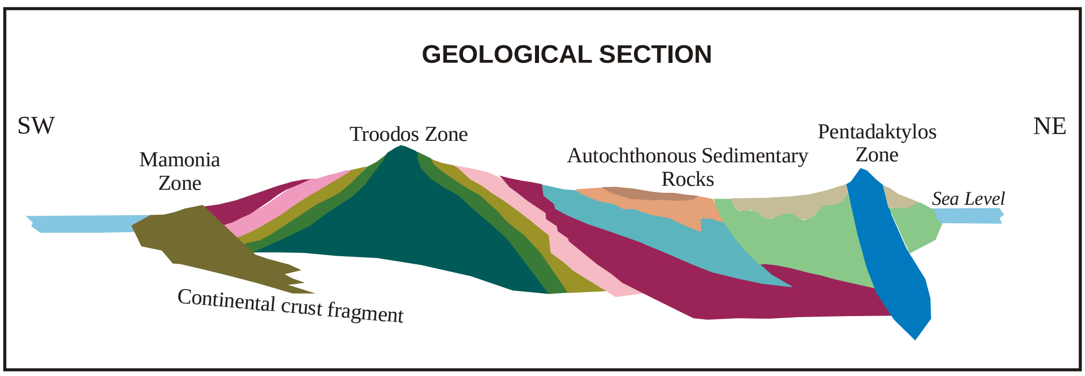

Fig. 3: SW-NE section showing the four geological zones and the geological structure of the island.

The Troodos Zone

The Troodos Zone or the Troodos Ophiolite dominates in the central part of the island and constitutes the geological core of Cyprus. It appears in two regions: in the main mass of the Troodos mountain range and in the Limassol and Akapnou Forest south of the range. It has a characteristic elongated domical uplift that exposes a central core of harzburgite tectonite and serpentinite diapir, stratigraphically overlain successively by a mafic-ultramafic plutonic complex, an extensive sheeted dike complex, extrusive volcanic rocks and sediments (Fig. 2). It was formed in the Upper Cretaceous (~92 Ma) on the Tethys sea floor, which at that time extended from the Pyrenees through the Alps to the Himalayas. The Troodos Ophiolite is regarded as the most complete and studied ophiolite in the world. It is a fragment of a fully developed oceanic crust, consisting of plutonic, intrusive and volcanic rocks and chemical sediments. The stratigraphic completeness of the ophiolite makes it unique. It was created during the complex process of oceanic spreading and formation of oceanic crust and was emerged and placed in its present position through complicated tectonic process relating to the collision of the Eurasian plate to the north and the African plate to the south. The stratigraphy of the ophiolite shows a topographic inversion, with the lower suites of rocks outcropping in the highest points of the range, while the upper rocks appear on the flanks of the ophiolite. This apparent inversion is related to the way the ophiolite was uplifted (diapirically) and to its differential erosion. The diapiric rising of its core took place mainly with episodes of abrupt uplift up to the Pleistocene (2 Ma).

Structurally, the Troodos Ophiolite consists of an elongated dome resulting from uplift caused by emplacement of the central serpentinite diapir (Gass, 1980). In the southern part of the ophiolite, the Arakapas Fault Zone, an E-W trending graben separates the main Troodos block from the Limassol Forest area. Both the Arakapas Fault and the Limassol Forest area are regarded as parts of the Arakapas Fossil Transform Fault (Gass *et al.,* 1994).

Mineralization in the Troodos Ophiolite is largely restricted to chrysotile asbestos and chromite deposits in the ultramafic assemblage and massive sulfide deposits in the pillow lavas. Small scattered occurrences of sulfide mineralization are also present in the harzburgites and dunites, in the gabbros and sheeted dike complex, but no economically viable deposits have yet been discovered.

The Mamonia Zone

The Mamonia Zone or Complex appears in the Pafos district in the southwestern part of the island. It constitutes a series of igneous, sedimentary and metamorphic rocks, ranging in age from Middle Triassic to Upper Cretaceous (230-75 Ma). These rocks, which are regarded as allochthonous in relation to the overlying autochthonous carbonate successions and the Troodos ophiolite rocks, were placed over and adjacent to the Troodos ophiolite during the Maastrichtian.

The Zone of the autochthonous sedimentary rocks

The Zone of the autochthonous sedimentary rocks (Fig. 2, 3, 4), ranging in age from Upper Cretaceous through to Pleistocene (67 Ma to recent), covers the area between the Pentadaktylos and Troodos Zones (Mesaoria) as well as the southern part of the island. It consists of bentonitic clays, volcaniclastics, mélange, marls, chalks, cherts, limestones, calcarenites, evaporites and clastic sediments. It is also referred to as the Circum-Troodos sedimentary succession.

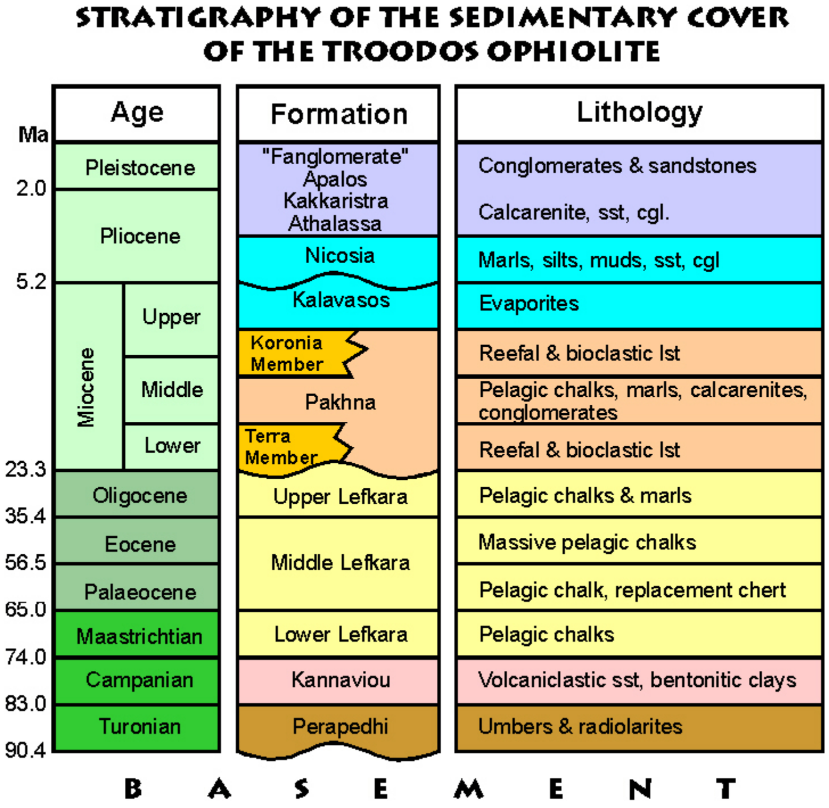

Fig. 4: Stratigraphic column of the sedimentary cover of the Troodos Ophiolite.

It is best exposed in the Mesaoria basin where it overlies unconformably all of the other Plio-Pleistocene Formations. The base of the Circum-Troodos sedimentary succession is marked by the Perapedhi Formation consisting of umber and radiolarite, which is overlain by the Kannaviou Formation, extensively exposed in western Cyprus. In the southern part of the island this formation was later deformed and mixed with various exotic blocks and it is referred to as the Moni Formation or Moni Mélange. The Kannaviou deposits comprise thick sequences, up to 750 m, of volcaniclastic sandstones and siltstones and bentonitic clays. These sediments have been dated as Campanian to mid-Maastrichtian on the basis of diagnostic foraminifera and radiolaria.

The Kannaviou Formation is overlain by the Lefkara Formation which constitutes typical pelagic marl and white chalk, with or without chert. Originally termed as the Lapithos Formation, its name was changed when it was realized that the type section close to Lapithos village was not typical of exposures elsewhere. Four lithologic units have been identified in the Lefkara Formation. They are, in ascending order, the Lower marl unit, the chalk and chert unit, the chalk unit and the Upper marl unit.

The Pakhna Formation rests on the Lefkara Formation and comprises two members of reef limestone, the Terra Member at the base and the Koronia Member at the top. The Lower Miocene Terra limestone is overlying the Lefkara Formation in places, in southwestern and southeastern Cyprus. Elsewhere in Cyprus, the Lefkara Formation is overlain by the typical Pakhna Formation. The typical Pakhna sediments are cream to buff-brown chalks and marls, which contrast sharply with the bright white chalks of the underlying Lefkara chalks. Another characteristic feature of this sequence is the occurrence of beds of variable thickness of calcarenite and locally developed conglomerates, which in the upper part of the Formation contain (in addition to shallow-water carbonate clasts) rock fragments derived from the Troodos ophiolite. Where exposed, the formation thickness is about 300 m, while in Mesaoria, the same sediments, mostly marly chalk and marl, are 375 m as revealed by two deep drill holes.

Coarse reworked carbonate sediments known as the Koronia Limestone, also containing conglomerates, coarse calcarenites and minor silts and marls, rest at the top of the Pakhna sediments south of the Troodos massif. This facies of the Pakhna Formation has not been identified at the Pentadaktylos Range, where the Kythrea Flysch is conformably overlain by up to 120 m of chalks and marls, with gypsum layers resting at the top of the succession.

At the top of the sequence there is a succession of evaporites, apparently deposited during a Messinian marine regression. These rocks, known as the Kalavasos Formation, constitute gypsum and gypsiferous marls, which occur in irregular beds or lenses of highly variable thickness around the Troodos massif. The evaporites mark the top of a mega-regressive sedimentary sequence overlying all of the geological terranes of Cyprus, as a result of the Messinian salinity crisis in the Mediterranean Sea.

A basal Pliocene transgression in Cyprus was followed by the deposition of the Nicosia Formation, whose dominant facies are green-gray to dark-brown calcareous clayey silts that usually show no sedimentary features. The silts pass upward into fine sands, which vary in thickness from 10 m to 50 m and are topped by thin conglomerate. The occurrence of calcarenites, sands and thin conglomerate at the top of the Formation are indicative of the final shallowing-up of the depositional basin. The Nicosia Formation has a maximum thickness of 900 m and spans almost the whole of the Pliocene.

The Nicosia Formation is overlain either by the Athalassa Formation or the Kakkaristra Formation. The Athalassa Formation is made up of a series of fossiliferous, medium- to coarse-grained, cross-bedded calcarenites, interbedded with sandy fossiliferous marls. In central and southwestern Mesaoria, the Athalassa calcarenites are replaced by a variable sequence of conglomerates and sands with minor calcareous sands and muds. These have an average thickness of 12 m whilst the Athalassa calcarenites may be as much as 50 m thick. Paleontological dating indicates Lower Pleistocene age for the Athalassa Formation.

The shallow marine Athalassa beds grade laterally to a sequence of fan-delta deposits, which include bay and lagoonal facies (Kakkaristra Formation). The Kakkaristra Formation occurs on the southern side of the Mesaoria basin and consists of a series of siltstones, cross-bedded conglomerates and fine-grained sands with conglomeratic intercalations. In places on top of the formation there is a thin lacustrine limestone. The maximum thickness of the formation is 15 m.

At the top of the Athalassa and Kakkaristra Formations there is a series of near-horizontal reddish fluvial muds and silts with some conglomerate (Apalos Formation). These deposits reach a maximum thickness of 60 m at the type locality, while elsewhere the thickness ranges from 10 m to 30 m.

The youngest (Pleistocene) sedimentary sequence on the island is the Fanglomerate. It comprises a very coarse, widespread alluvial fan deposit, made up of a coarse, angular, poorly sorted conglomerate. The clast lithology in this and the other Plio-Pleistocene conglomerates is almost exclusively ophiolite-derived, marking the very rapid uplift and erosion of the Troodos massif at this time.

NEOTECTONICS IN CYPRUS

A project on the active tectonics of Cyprus was concluded in 2005 (GEOTER, 2005) in collaboration with French and Armenian experts, aiming to determine and analyze the tectonic structures that can produce future significant earthquakes, as well as to give the seismotectonic parameters of these structures for further seismic risk mitigation studies. Based on the analysis and morphostructural interpretation of aerial photographs and satellite images, as well as detailed neotectonic field investigations, the study has identified and mapped Quaternary faults and has defined the main seismotectonic and geometrical characteristics of them.

Estimating the size of earthquakes that can occur along a fault is a fundamental element of any analysis of seismic hazard. Estimating earthquake size, however, is not simple and many approaches and methods have been used in the past (DePolo and Slemmons, 1990). The diversification of methodologies is due, in part, to the variability in the character and expression of seismic sources and in the amount and types of available data. Three of these approaches were used in this study, namely the historical approach (studying of earthquakes from historical data), the paleoseismic approach (studying of the prehistoric earthquakes including trenching studies, quantitative tectonic studies, geomorphological studies and age-determination techniques) and the source-characterization approach (involving analysis of the physical characteristics of potential seismic sources and assigning of correlative earthquake size).

TODAY'S TRIP

Today's excursion is designed to give the participants the opportunity to view evidence of neotectonic activity in Cyprus.

We will start from the Hilton Park Hotel and take the main road from Nicosia to Larnaca. Our first stop will be at Cape Kiti. We will then travel toward Limassol, and stop near Finikaria village. We will then head to Pafos and stop near Kouklia village. Our last stop will be along the Pafos-Pissouri road near the village of Pissouri.

After lunch at the Petra tou Romiou Restaurant, we will visit the Kourion archeological site, which is one of the most important archeological sites of Cyprus. The Theater that was originally built in the 2nd century B.C. and redesigned during the 1st century A.D. was enlarged to its present size and adapted to accommodate gladiator games in about A.D. 200. The trip will continue from Kourion to Nicosia.

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Cape Kiti Fault Stop

Harrison, Richard [1]*, Tsiolakis, Efthymios* [2]

[1] United States Geological Survey
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Geological mapping along the Larnaca Fault Zone (LFZ) has found structural evidence of left-lateral strike-slip faulting during the Late Pleistocene and Holocene. Trending NNE, the LFZ has more than 30 km of onshore strike length and consists of several braided, steeply dipping fault strands. Bathymetric data suggest that the LFZ extends many more kilometers to the SSW, where it intersects the Cyprus Arc, a plate boundary between the Anatolian and the Sinai microplates, which are parts the Eurasian and African plates, respectively. LFZ is interpreted as a sympathetic Riedel shear to the Cyprus Arc; both are seismically active.

Exposures of the LFZ at Cape Kiti show that it has experienced several episodes of faulting (Harrison *et al.*, 2010), which extend at least back to the Pliocene (as borehole EG 1/2005 reveals). The borehole, located 60 m west from the fault scarp, penetrates successively 16 m of Holocene to Late Pleistocene sediments (thin colluvium layer, less than 2 ka old), the Pervolia alluvial fan (30-13 ka old), the Late Pleistocene beach gravels and the Late Pleistocene Kiti Tower sand (~24-50 ka old) and 20 m of Pliocene sediments. The Pliocene marls, reaching a depth of 16 m below surface at the west side of the fault scarp, are totally absent from the east side, a fact that reveals the Pliocene (at least) history of the fault.

The latest two events appear to have occurred just prior to ~16,000 yrs before present (BP) and post ~6,000 yrs BP. The first event has evidently occurred prior to ~16,000 yrs BP, as the Kiti Tower sand is affected by the fault (found at both sides of the fault scarp). Also, the Latest Pleistocene Pervolia alluvial fan (~30-13 ka BP), with a paleosoil horizon (~18 ka BP) at the west side of the fault scarp, is affected from the fault. It is evident that the latest event occurred post ~6,000 yrs BP, as a Holocene beach gravel deposit that was deposited ~6-7 ka BP has been influenced by the fault. A wedge of these gravels resting on a thin layer of the Kiti Tower sand is found at the fault scarp. The gravel clasts are almost tilted in vertical position above the intensely deformed yellow bioturbated Miocene Pakhna Formation chalk beds, dipping 65° SE.

There is no evidence that the fault has been active in the past ~2,000 yrs, as the recently deposited colluvium, which thins eastward and disappears over a distance of a few meters, is undisturbed.

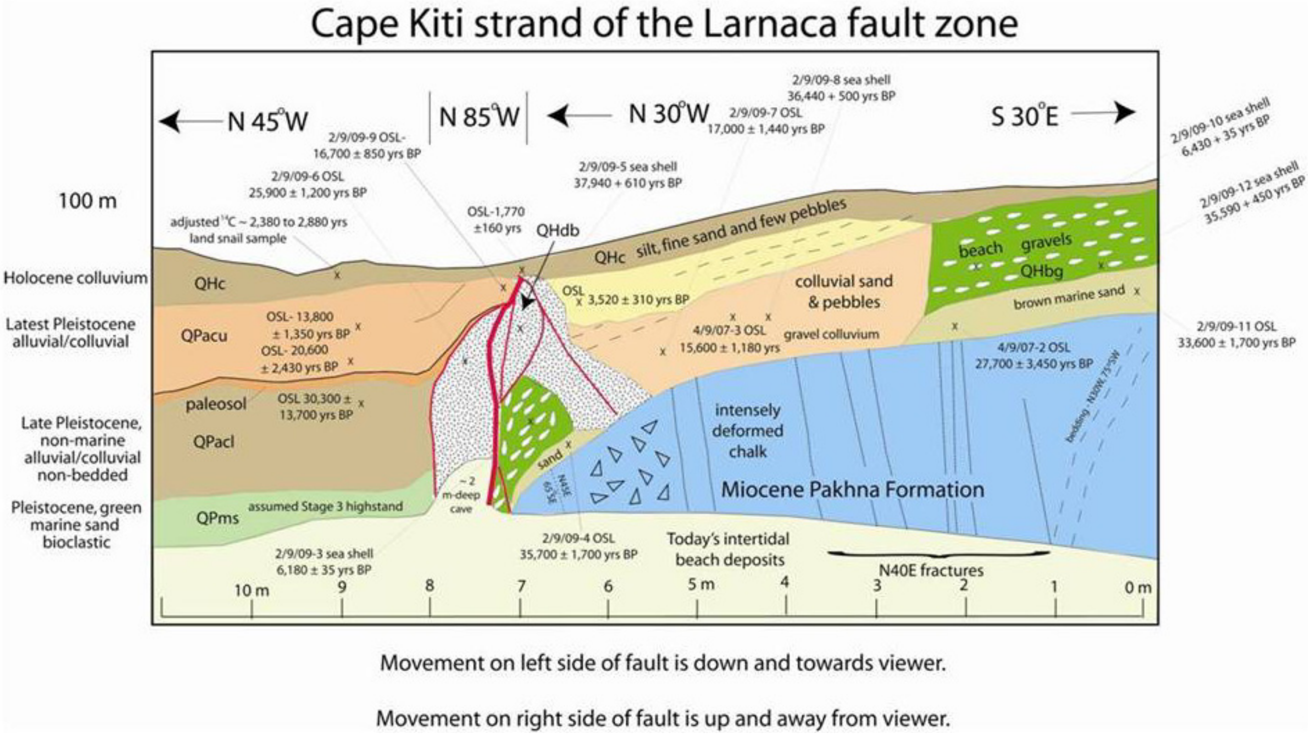

Fig. 5: A schematic diagram showing the relationship between the fault and the strata (kindly provided by R. Harrison).

FINIKARIA STOP

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The Yerasa fault system is a sub-vertical, en-echelon strike-slip fault system with a right-lateral sub-horizontal Quaternary displacement and constitutes of several faults. The faults are orientated N130°E in the northwestern segment, N110°-115°E in the central segment and N110°-120°E in the southeastern segment, where they have progressively curved to an E-W orientation. Some of the faults of the Yerasa fault system have been reactivated during the Quaternary while some others have not. The Quaternary trace is approximately 25 km long, between Ayios Mamas village to the northwest and Ayios Tychonas village to the southeast. At its northwestern extremity, the fault system dies out in a 941-m-high push-up hill west of Ayios Mamas village. At the southeastern end, from southeast of Yermasoyia River up to east of Ayios Tychonas village, it gradually dampens in a three-segment horsetail.

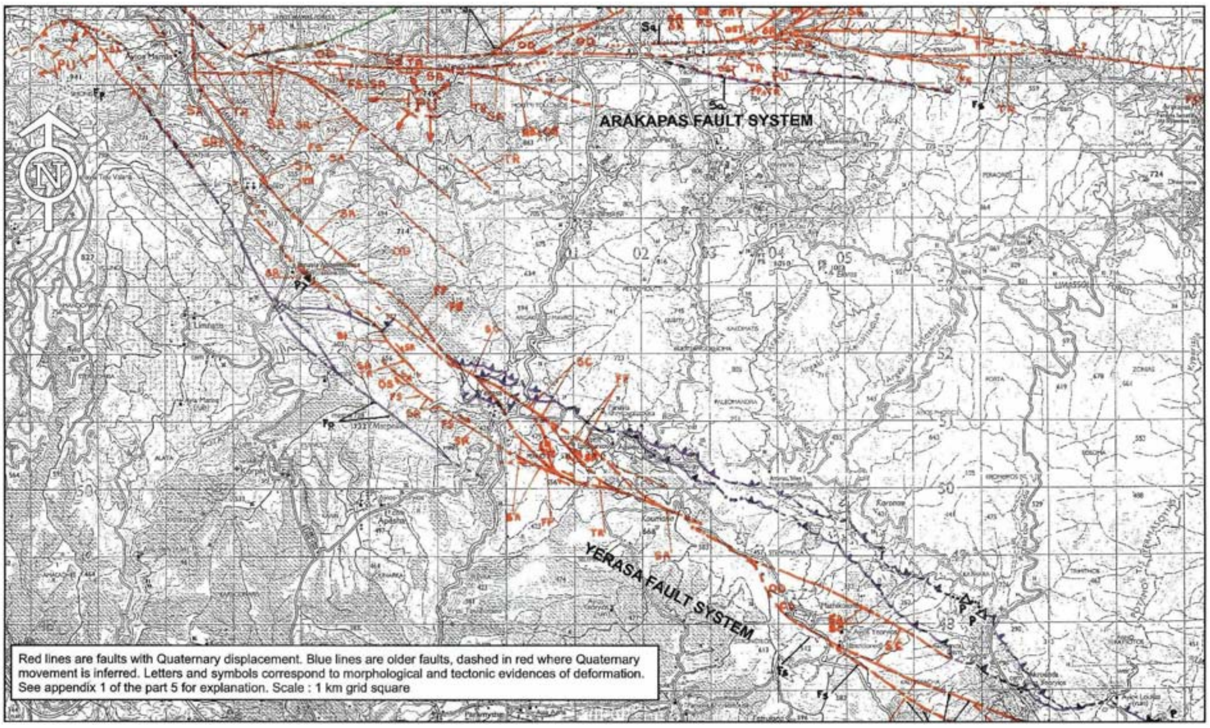

Fig. 6: Map showing the Yerasa fault system and the Anti-Troodos frontal thrust.

In the broader area of the Finikaria stop, the Yermasoyia fault is situated in the river valley from the reservoir to the south. It belongs to an open fault striking N160°-170°E, spreading out the two valley sides with two parallel faults with no clear vertical differential movement; the first divergent fault of the horsetail segment of the Yerasa fault system cuts vertically and offsets the Yermasoyia stream in the central part of the area, and the WNW-ESE Anti-

Troodos frontal thrust at the northern part, where the mantle rocks thrust on pillow lavas. The Anti-Troodos frontal thrust appears to be inactive, as it does not exhibit any morphological signs of Quaternary reactivation.


Fig. 7: Fault scarp (red dotted line) of the Yerasa fault in the Finikaria village area, view to the south (left). Aerial view of the Yerasa fault system from Finikaria village looking northwest (right) showing offset streams, epigenic gorge, shutter ridge, faulted terraces and anticline across the river.

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Fig. 8: Anticline structure along the Yermasoyia River.

KOUKLIA FAULT STOP

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The area between the Khapotami River mouth, the Kouklia village and the Asprokremmos Dam is an oblique segment of the major 5-km-long Pafos Thrust System (PTS). The whole zone may correspond to the surface expression of a deep lateral ramp shifting the PTS front by 3.5 km. This zone, together with the one situated further to west, north and northeast of Yeroskipou village, are the only zones where the extent of deformation is clearly observed in recent deposits; this shows that the PTS is an active system with a fairly high slip rate.

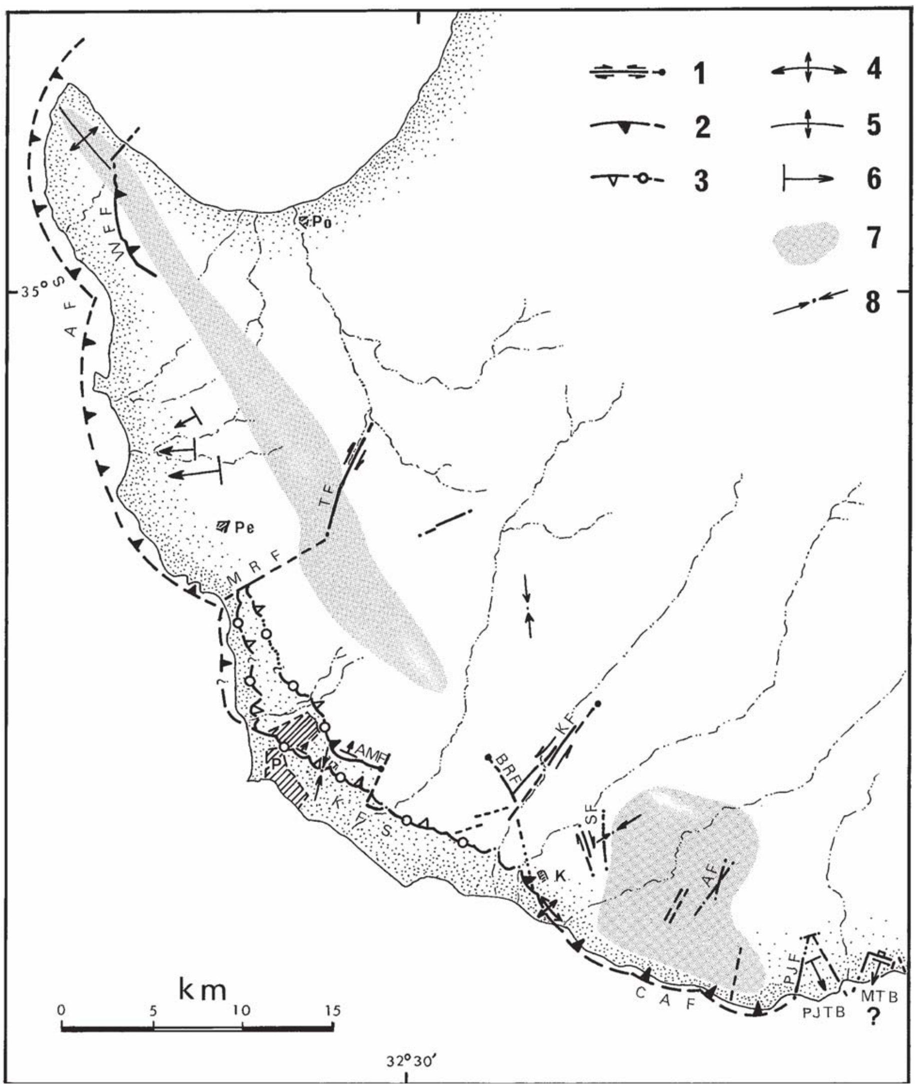

Fig. 9: The major Pafos Thrust System.

In the broader area of the Kouklia Fault stop, two main low-angle fault planes are located 200 m from each other. The eastern fault cuts off and folds gently the marine terrace gravels and the chalks of the Pakhna Formation below. The western fault, which is at the Kouklia fault stop, has a small ramp very close to the surface, which produced a fault-bend anticline folding together the Upper to Middle Pleistocene marine gravels and the chalks of Pakhna Formation on an overall length of about 750 m. The marine terrace deposits and the Pakhna chalks below are folded up to 45° at the eastern flank of the fold, but are almost vertical on the western flank, resting on top of another younger marine terrace deposit. The probable age of both terrace deposits was determined at the Upper-Middle Pleistocene, depending on the weathering and the weak cementation of the gravels.

Fig. 10: Extremity of the curved anticline cut off by the Pissouri-Pafos road.

An exploratory trench that was excavated at the bottom of the southern fold front scarp revealed that the fault has a strike N010°E and dips 35°E at the eastern end of the trench at the base of the anticline. It dips 05°E immediately to the west and remains sub-horizontal over a distance of approximately 4 m, revealing the existence of the ramp near the surface. Also the bedding of the lower younger marine terrace gravels changes gradually from 80°W to 40°W westward, showing a synsedimentary tilting in numerous successive phases of fault displacement.

The fold is sigmoid with axial plane undulating between N010°E and N145°E. The sigmoid geometry shows the existence of a fairly strong right-lateral component on the major thrust fault plane. This component is the result of the obliquity of this fault segment regarding the whole orientation of the major PTS and also because of the right-lateral shifting produced by the Kouklia-Xeros Potamos transverse zone, between the Cape Aspro and the Ktima faults.

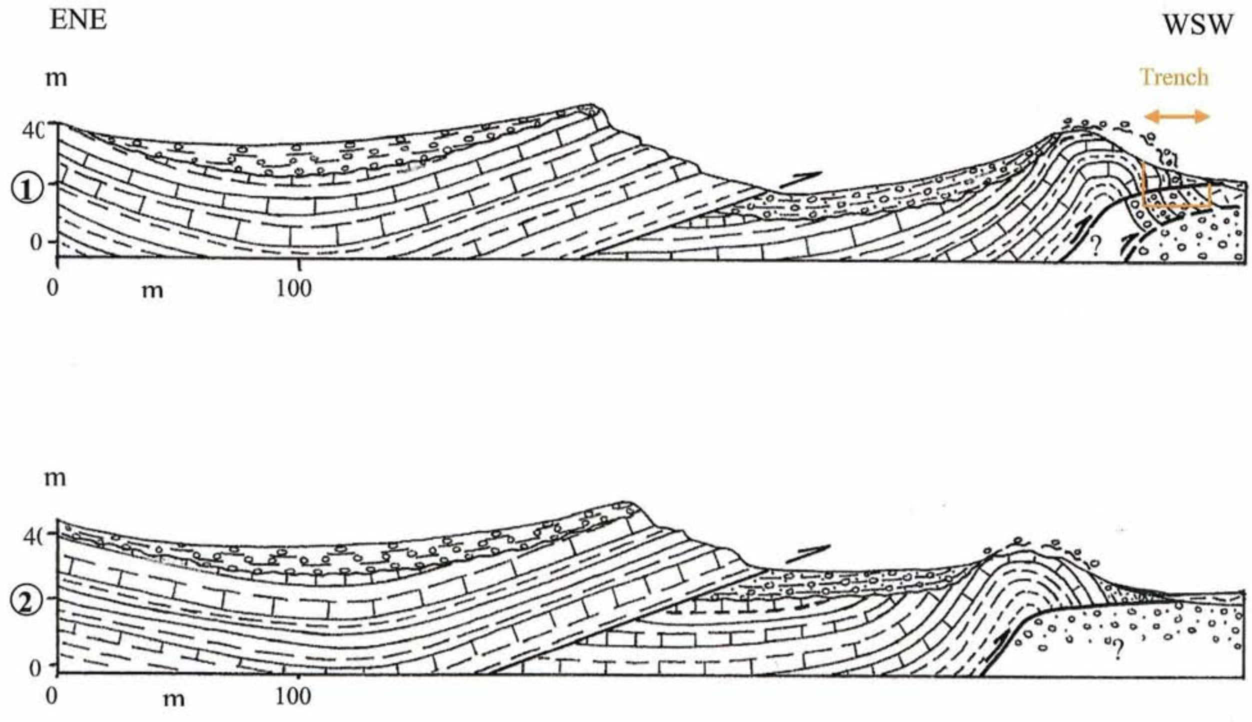

Fig. 11: Schematic diagram showing the Cape Aspro thrust frontal deformations between the Khapotami River and the Yiakoupis Stream and the location of the exploratory trench. Distance between cross sections 1 and 2 is approximately 500 m.

PISSOURI STOP

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The area between Kouklia village to the west, Avdimou bay to the east and Pano Archimandrita village to the north is a wide and uplifted zone, where Quaternary marine terraces are uplifted by at least 300 m and fanglomerate deposits are up to 500 m high on top of an erosional surface. The Plio-Pleistocene marine fan delta terrace (Stow *et al.*, 1995) at the Pissouri area (Pissouri Plateau) to the south ends in a more than 200-m-high sea cliff between Cape Aspro and Petra tou Romiou.

Only an offshore Quaternary reverse or thrust fault, very close to the coast, could produce such an upthrust, running N110°E parallel to the coastline, over a distance of about 15 km between Cape Aspro and the Khapotami river mouth. From Khapotami River up to Kouklia village the fault orientation changes, cutting across the coastline and extending on land.

Fig. 12: Aerial view of the Cape Aspro cliff.

The dip of the offshore fault is certainly high and it is probably not a blind thrust. The large extension of the uplifted zone implies that it could be a classic flat ramp system at crustal scale. The reverse vertical component is certainly very dominant, but a small horizontal component is also foreseeable.

On land deformation is observed in the east and west uttermost ends of the uplifted area. Additionally, gravity faults are observed near steep and deep river valleys as a result of the gravitational movement of moderately thick sedimentary blocks, which are resting directly on the Kannaviou bentonitic clays and/or on mudstones and siltstones of the Mamonia Formation. Such gravity faults are observed along the Limassol–Pafos motorway within the uplifted area.

Fig. 13: Gravity faults along the Pissouri-Pafos motorway.

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