Earthquake Archaeology

Archaeoseismology along the Alpine-Himalayan seismic zone

Proposed by:

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1. Aims and Background

Rationale

Archaeoseismology aims at studying ancient earthquakes through indicators left in the archaeological record. Although it has a lineage that extends back to the late 19th Century, it is essentially a young and emerging discipline that has met with much reservation from many earthquake scientists. Many of those scientists question whether cultural phenomena – destruction layers, structural damage to man-made constructions, cultural piercing features, indications of repairs, inscriptions, historical accounts and myths, etc – can reliably be used as earthquake indicators at all. Skeptics primarily criticize the indiscriminate use of earthquakes as a ‘deus ex machina’ to explain otherwise inexplicable events in the history of a site and to add drama and conjecture to the history of a site. Moreover, in cases where there is poor spatial and/or temporal resolution, there exists a danger of amalgamating or duplicating past seismic events. The concern is that inferred earthquakes, supposedly proven by archaeologists, will end up as a factual seismic event in a geodynamic interpretation by geologists, in an assessment of the seismic hazard by seismologists, or in mitigation efforts of seismic risk by engineers.

The problem seismic-hazard practitioners face, however, is that the instrumental record of earthquakes is too short and the historical seismic record too incomplete. Historical catalogues, for example, record only a tiny proportion of the sizeable shocks that have struck a region over centuries and millennia. That missing population of earthquakes clearly tempers reliable seismic-hazards assessments. The archaeological record, however, can bolster and augment that historical archive. What’s more, in extending the earthquake record beyond written sources, archaeoseismology serves as a bridge between instrumental and historical seismology, on the one hand, and palaeoseismology and earthquake geology, on the other hand. Only the integration of all potential evidence for past earthquakes will enable make possible a better understanding of the complex earthquake history of a region and archaeoseismology has the potential to be a legitimate and complementary source of seismic-hazard information.

What holds archaeoseismology back from being a mature scientific discipline is its lack of a rigorous and transparent methodology. The realization of the need for a systematic, transparent methodology has inspired many workers to propose procedural schemes for archaeoseismology. But in most cases these schemes are designed from within a single scientific discipline, revealing the principal hubris of archaeoseismology, the interdisciplinary nature of the evidence that confronts it. Archaeoseismology calls upon the expertise of historians, anthropologists, archaeologists, geologists, seismologists, geophysicists, architects and structural engineers. Integrating the principles and practices of such a wide range of sciences is archaeoseismology’s greatest challenge and its foremost attraction. Most archaeoseismological case studies limit cross-disciplinary links to modest collaborations between archaeologists and geologists, between archaeologists and engineers, between geologists and seismologists, etc. While many practitioners recognize the need for a fully integrated approach, as yet, broad partnerships between archaeologists, geologists, seismologists, geophysicists, architects, engineers and historians have still to be realized.

This project seeks to establish an inclusive framework in which such a multidisciplinary approach can take root. It aims to encourage the transparent discussion between a wide range of specialists, to promote a common vocabulary and understanding of purpose, and foster a standardized methodology based on the consensus of those active in the field of archaeoseismology. Such an ambitious goal can only be effected under the auspices of a long-term and global partnership, and IGCP is ideal for our purposes. In this respect, the current project proposal complies with the primary aim of IGCP, i.e. “to facilitate international collaboration amongst scientists from around the world in research on geological problems, particularly between those individuals from more industrialized and those from developing countries … to promote the use of geosciences in global issues including … the reduction of the adverse effects of natural disasters …”.

Moreover, the current project proposal is central to one of the topics of particular interest to IGCP, namely “Geohazards: Mitigating the Risks”.

Facilitating such a broad ranging, multidisciplinary discussion on archaeoseismology is the primary aim of the proposed IGCP project. To that end, we have brought together the principal practitioners in archaeoseismology and from that nucleus we will, over the next five years, expand and integrate their
activities with specialists from as many disciplines as possible. But there is a second strategic objective that this project addresses and that is to extend the geographical provenance of archaeoseismological studies beyond its traditional territory of the Eastern Mediterranean and Middle East. Innovative archaeoseismological research has emerged in many parts of the globe, but its roots lie in the earthquake-prone region atop the Alpine collision zone between Africa and Eurasia. This project takes the opportunity to expand that archaeoseismological know-how into neighbouring regions that share much cultural and geodynamic continuity. The Alpine-Himalayan seismic zone will provide a coherent but challenging ground for developing archaeoseismological principles and practices.

Aims

Objective 1 – Archaeoseismological methodologies: Principles and Practices

The development of rigorous but practicable archaeoseismological methodologies is a key step in achieving our ultimate goal, integrating archaeoseismological evidence in seismic-hazard studies. This objective is achieved by:

1. bringing together scientists that have published on methodological issues in archaeoseismology to discuss the different methodological approaches and to make an attempt to propose a standardized methodology (scientific & field meetings in established 'laboratory sites');
2. inviting specialists from allied disciplines (geology, geomorphology, seismology, geophysics, architecture, engineering, archaeology, history, anthropology, ethnography, etc) together in the field (field meetings) to help forge interdisciplinary partnerships in studying new or less well-studied archaeological sites;
3. fostering knowledge transfer between the different disciplines (workshops/field schools); to create a common archaeoseismological knowledge platform (archaeological sciences, earthquake geology and geophysics, architecture and structural engineering, etc) that can be taken to other regions not addressed directly in this initiative.

By linking the past with the future, we feel that this work will accrue important scientific and societal benefits. By 'looking back' we can reconstruct earthquake histories that will improve archaeologists and historians understanding the cultural history of a region as well as providing complementary information on its long-term seismic hazard. By 'looking forward' we contribute to mitigation efforts of seismic risks, especially for the cultural heritage sites where much of our data is collected. As the project develops, our intention is to bring in earthquake engineers, civil engineers and architects from as wide a range of cultures to indentify typologies of anti-seismic design and to reveal traditional good building practices.

Objective 2 – Archaeoseismology in the Alpine-Himalayan seismic zone: Archaeoseismic cultures

The second objective is to take archaeoseismology out of its 'Mediterranean cradle', extending research to new territories that share a comparable seismotectonic setting and a contiguous cultural and historical context. In this respect the Alpine-Himalayan seismic belt is of particular interest because it is home of some of the most ancient civilisations in the world. It might thus be expected to have the clearest signs of cultural evidence of ancient seismic catastrophes.

This objective will be to take the Mediterranean experience eastwards, following the seismic belt into Central and Southeast Asia. Our goals is to identify and foster archaeoseismological studies in these new regions and thereby promote new ‘seed points’ for future archaeoseismological work in these earthquake-prone developing countries. A key element of this will be outreach and capacity building.

Objective 3 – Outreach

The combination of seismic destruction and ancient cultures is a powerful mix that has the potential to be of interest to a wide group of people beyond the normal academic peer-group. Although much of the published output of our project will be scientific works (edited research books, journal special issues, etc), much attention will also be given to an outreach programme that uses our fresh and novel perspective to communicate earthquake science and seismic hazard to a wide public audience. All the project leaders are actively engaged in geoscience communication and there is considerable experience in the team to 'package' our research ideas for mass popular culture. As well as outreach activities for local communities at each of the field meetings, science journalists and television producers from various international media organisations will be invited to appropriate meetings.
Previous work

Manuel Sintubin

The work of the Leuven group has focused on the archaeological site of the Roman-Hellenistic city of Sagalassos in Southwest Turkey. The integrated application of different approaches (geology, geomorphology, geophysics, palaeoseismology, archaeology), both on the site and within a wider region, has lead to the possible identification of a potentially hazardous fault. The extensive Sagalassos data set has been the foundation on which a new attempt is made to establish a standardised methodology for archaeoseismology (in collaboration with Iain Stewart). Currently archaeoseismological research efforts are extended to other sites in Southwest Turkey in collaboration with the Ruhr-Universität Bochum (Germany) and Erhan Altunel. Prospective work has been done in Crete in collaboration with the Université Catholique de Louvain (Belgium).

Iain Stewart

Iain Stewart has promoted interdisciplinary earthquake science research for the last decade, recently hosting international conferences such as Environmental Catastrophes in the Holocene (IGCP490) and co-editing research volumes on archaeoseismology. His own research has been focused on active faulting and palaeoseismology in Greece, western Turkey and eastern Sicily, adopting a field-based approach that integrates coastal, geomorphological and archaeological data to determine recent faulting histories. Increasingly, his research has a strong outreach dimension. His palaeoseismological work on the Aegean region was a collaboration with the EU’s CORSEIS earthquake science project and the Helike Archaeological Project, and led to the BBC Horizon programme, Helike – The Real Atlantis. His archaeoseismological interests subsequently featured in the BBC Horizon programme Earthquake Storm. He has ongoing research collaborations with Manuel Sintubin (archaeoseismological methodologies), Erhan Altunel (seismic damage to archaeological sites) and Luigi Piccardi (cultural responses to earthquakes). On the outreach front, he has had several television programmes on geology commissioned with major science broadcasters (BBC, Discovery, National Geographic, ZDF) and currently has major projects in development with BBC Science on the broad theme of geology and human history.

Tina Niemi

As a Quaternary geologist specializing in archaeoseismology, geoarchaeology and palaeoseismology, Tina Niemi has studied the geological, geophysical and archaeological evidence of seismic activity, active tectonic deformation, and environmental change on the northern San Andreas fault in California (U.S.A.), the Dead Sea transform fault in Israel and Jordan, and the Humboldt fault in Kansas (U.S.A.) as well as sedimentological studies in Greece, South Africa and The Bahamas. Over the past 25 years, Tina Niemi has participated on ten multidisciplinary archaeological excavations and geoarchaeological survey teams in Jordan, Israel and Greece (including el-Maghtas, Pella, Umm el-Jimal, Roman Aqaba, Wadi ‘Arabah, Qasr Tilah, Qumran, Nemea, Argolid and Thronion). She was the staff geologist on the Roman Aqaba Project between 1994 and 2002. Since 1996, Tina Niemi has directed nine field seasons and excavations of the Wadi ‘Arabah Earthquake Project (WAEP) – a cooperative research project between the Jordanian Department of Antiquities, Yarmouk University and Al-Balqa’ Applied University (Jordan) and UMKC in affiliation with the American Center of Oriental Research. The WAEP has quantified liquefaction susceptibility, the ancient Islamic city wall, and fault rupture in Byzantine ruins in Aqaba and slip rate and palaeoearthquakes at the Qasr Tilah site in Jordan. Recent collaborations include a Middle East Regional Cooperation geophysical project between Israel and Jordan to map offshore faults in the Gulf of Aqaba/Eilat, and a project to document the ancient earthquakes in the Negev with Dr. Tali Erickson-Gini of the Israel Antiquity Authority.

Erhan Altunel

Erhan Altunel is Professor at the Department of Geology of Eskişehir Osmangazi University. He has worked on over 15 national and international scientific projects. He led three projects on historical earthquakes along the Menderes and Gediz grabens (western Turkey), supported by TÜBİTAK (Scientific and Technological Research Council of Turkey). He is currently leading a project (supported by TÜBİTAK) on archaeoseismology and palaeoseismology of the Büyük Menderes fault zone (western Turkey). He led an EC-funded project (FP5 programme) on the Turkish section of the Dead Sea fault zone (APAME). His research mainly focuses on active faulting, palaeoseismology and archaeoseismology in Turkey. He applies recent techniques such as ground penetration radar and ground LIDAR in his field studies.
2. Significance

In recent years the scientific activity in the field of archaeoseismology has been very intense, as reflected in a number of books and special issues of scientific journals (see § 8.3). But the impression remains that scientific progress is rather slow and that research efforts are somewhat scattered and lack a high visibility.

In the International Union for Quaternary Research (INQUA) initiatives in archaeoseismology are taken by the Subcommission Palaeoseismicity (part of the commission ‘Terrestrial Processes, Deposits and History) (President: A. M. Michetti; Vice Presidents: K. Okumura, P. Silva) (http://www.apat.gov.it/site/en-GB/Projects/INQUA_Scale/default.html).

In the European Seismological Commission (ESC) (http://www.esc.bgs.ac.uk/) two working groups are active in the domains that are of interest in the project: the Working Group Archaeoseismology (responsible: F. Galadini, S. Stiros) and the Working Group Historical Seismology (responsible: P. Albini, P. Labak). The former working group organised the workshop ‘Archaeoseismology at the beginning of the 21st Century’ in 2004. The results of this meeting are reflected in a special issue of the Journal of Seismology, published in 2006 (see § 8.3). The objectives of the proposed IGCP project to a large extent comply with the main objectives of the ESC Working Group Archaeoseismology, i.e. focusing on the methodological aspects, bringing experts of different disciplines together, increasing the awareness on archaeoseismology in the scientific community, and develop archaeoseismology into an independent and mature scientific discipline. The efforts of the working group certainly serve as the foundation on which this project hopes to build.

The European Commission project ‘Archaeoseismology and Palaeoseismology for the Protection of Cultural Heritage and Archaeological Sites in the Middle East’ (APAME, 2003-2006) (http://eost.u-strasbg.fr/~apamea/) (coordinator: M. Meghraoui) is a third initiative in which archaeoseismology played an important role. This initiative focused on the region along the Dead Sea fault (Syria, Jordan, Lebanon and Turkey).

Finally, we have to mention a parallel project pre-proposal by Spiros Pavlides (Aristotle University, Thessaloniki, Greece), entitled ‘The past as key to the future. Prehistoric and historical earthquakes in Eastern Mediterranean as a key to better contemporary seismic hazard assessment’ within the framework of the European Union-funded COST Actions (European Cooperation in the field of Scientific and Technical Research). This project proposal has complimentary objectives to the current IGCP project proposal (objective 1 - § 8.1), with a focus on the Eastern Mediterranean.

All the initiatives, taken by these different groups, demonstrate a clear consensus on the strategy to follow with respect to archaeoseismological work, a strategy that is also reflected in the main objectives of the proposed IGCP project. The project differs, however, in two aspects with the above-mentioned initiatives. In this respect this project is significant, an opinion shared by those who showed interest in participating in the project (see Supplement 3 with the confirmation e-mails).

First of all, the project is intended to have a global approach, creating an international platform with respect to archaeoseismology. Moreover, by putting the main focus on archaeoseismology a high visibility of the discipline in the international scientific community is assured, which will definitively contribute to its scientific advancement. This international platform will intensify the networking not only between individual scientists and research groups of different disciplines but also between different organisations in which archaeoseismology is of interest. The projects intent to promote new and intensify existing collaborations between scientists of as many different disciplines concerned as possible, as well as to transcend the regional framework of most current research efforts by bringing scientists together from all over the world working in completely different geodynamic and cultural settings. This IGCP project may become the common platform where activities in the field of archaeoseismology are coordinated.

Secondly, the proposed project has the objective of enlarging the regional extend of archaeoseismological research. The main emphasis is put on the entire Alpine-Himalayan seismic zone, bringing archaeoseismology from the Mediterranean to the Pacific. On the one hand, archaeoseismological research will be introduced into new territories, creating ‘seed points’ for future research. On the other hand, relatively unknown archaeoseismological initiatives within the entire region will be brought forward and integrated in the international archaeoseismological knowledge base.

A better assessment of the seismic hazard has significant societal relevancy for the entire Alpine-Himalayan region, of which the majority of countries are developing countries. The proposed project can make an important contribution to this ultimate objective. An important aspect is the knowledge transfer, achieved by (1) enabling scientists of these countries to participate to scientific meetings within the Mediterranean ‘cradle’ of archaeoseismology, allowing them to extend their observational knowledge base; (2) training new expertise on site in these countries and stimulating the public awareness with respect to earthquake hazards. These are primary aims of the IGCP, for which IGCP funding is indeed crucial for the success of this project.
The proposed IGCP project builds on the IGCP490 ‘The role of Holocene environmental catastrophes in human history’ (Leroy, S. & Stewart, I. – 2003-2007) and the ICSU project ‘Dark Nature’ (Leroy, S. – 2004-2005). One particular aspect of these past projects, i.e. earthquake hazard, is singled out and elaborated in this project proposal.

3. Present state of activities in the field of the proposed project

Since the beginning of archaeoseismology, it has been recognised that both the need of a systematic, transparent standardised methodology and an interdisciplinary collaboration between specialists from a wide range of scientific disciplines (Galadini et al. 2006b, Guidoboni 2002) are prerequisites for a general acknowledgement of this young scientific discipline. As already pointed out by Nikonov in 1988 the development of such a methodology should be subject to a continuing process of improvement that can only be achieved by collaborative teams of seismologists, geologists, archaeologists, architects and historians. This view has been repeated by later workers (Antonioli et al. 2006, Galadini et al. 2006b, Guidoboni 1996, Rapp 1986) and inspired many workers to propose methodological schemes. These schemes are essentially qualitative, being limited to lists of points of interest (Galadini et al. 2006b, Karcz & Kafri 1978, Nikonov 1988, Rapp 1986, Stiros 1996), questions (Guidoboni 2006) or flow charts (Galadini et al. 2006b) that ought to be considered during the investigation of an archaeological site. Hinzen (2005) introduced a more quantitative scheme in the form of a feasibility matrix for archaeoseismological findings that evaluates a probability of occurrence of the proposed ancient earthquakes, and which can be directly used as a weighting factor in probabilistic-based estimations of the seismic hazard. Following the same philosophy Sintubin & Stewart (submitted) designed a comprehensive, semi-quantitative standardised procedure, systematically treating the uncertainties inherent to the archaeoseismological record. With the resulting scheme they, moreover, attempt to integrate in a consistent and well-structured way the qualitative schemes proposed, enabling a transparent discussion between specialists with respect to the reliability of the archaeoseismological evidence and providing the excavator director a guide for an interdisciplinary research program during the excavations of an archaeological site in a seismological perspective. In this respect, the methodology proposed may constitute a significant step in the integration of archaeoseismology in seismic-hazard studies, a generally accepted concern (see preface in Galadini et al. 2006a).

The majority of the methodological developments has been grafted on archaeological investigations in the Eastern Mediterranean and the Middle East, with a strong dependence on identifying structural damage to buildings and other cultural remains at specific sites (Stiros 1988, 1996). In such studies, the discrimination of seismic effects is often made long after excavation, conservation and restoration works, which in many cases can be responsible for the destruction (or creation) of possible traces for ancient earthquakes. Other uses of archaeoseismological data exist, most notably the use of offset cultural relics (e.g. occupation layers) as piercing points from which to derive fault displacement and slip rates within palaeoseismological studies (Hancock & Altunel 1997, Marco et al. 1997, Meghraoui et al. 2003, Noller 2001, Noller & Lightfoot 1997), but in general the methodological impetus has been in diagnosing the cultural signature of seismic effects. A common concern in archaeoseismology, therefore, is finding reliable criteria to identify palaeoearthquakes on archaeological sites (cf. Ambraseys 2005,2006). To this end, there is a wide consensus that all other causes should be excluded before assigning damage a seismic origin. There is also a broad agreement that earthquakes should not be considered by the excavators as a ‘deus ex machina’ (Noller 2001) to explain the otherwise inexplicable or as conceivable hypotheses unless evidence suggests otherwise (Nur 2002), but instead should be the ‘explanation of the last resort’ (Rapp 1986). Furthermore, most of the practitioners emphasize the need for an integrated approach by a multidisciplinary team of archaeologists, geologists, geomorphologists, geophysicists, seismologists, architects and historians (Antonioli et al. 2006, Galadini et al. 2006b, Guidoboni 1996, Nikonov 1988, Rapp 1982), ideally all working together during the excavation (Galadini et al. 2006b, Guidoboni 1996, Noller 2001). Even then, it is acknowledged that interpretations will still be confronted with a number of assumptions (Guidoboni 1996), much subjectivity (Nikonov 1988) and varying degrees of uncertainty (Guidoboni 1996).

The research efforts during the last two decades have led to significant progress with respect to archaeoseismology. This is reflected in an extensive collection of publications. It is definitely not our purpose to give an inventory of this extensive publication list. Therefore we just focus on a number of synthetic works, published as books or special issues of international journals.


This book is the first synthesis of the state-of-the-art on archaeoseismology. It is the result of a 1991 meeting on archaeoseismology, focusing on facilitating communication between specialists of different discipline.


- Vittori, E. & Comerci, V. 2004. The INQUA Scale. An innovative approach for assessing earthquake intensities based on seismically-induced ground effects in natural environment. In: Memorie descrittive della Carta Geologica d’Italia 67. Agenzia per la Protezione dell’Ambiente e per i Servizi Tecnici, Roma, 118. (revised version of the scale (ESI2007) has been presented at the XVII INQUA Congress in Cairns (Australia) and ratified by the INQUA executive Committee; see http://www.apat.gov.it/site/en-GB/Projects/INQUA_Scale/default.html) Although not directly related to archaeoseismology, this work is relevant in the current project, because an integration of calibrated archaeoseismological evidence in the ‘Environmental Seismic Intensity Scale’ (ESI2007) is one of the objectives of the current project.


- Galadini, F., Hinzen, K.-G. & Stiros, S. C. 2006. Archaeoseismology at the Beginning of the 21st century, Journal of Seismology 10. This special issue is the most recent state-of-the-art on the progress in archaeoseismology. The papers in this issue reflect the increasing tendency towards multidisciplinary investigations on archaeological sites, as well as the convergence with respect to different archaeoseismological approaches. This work is the result of discussions within the framework of the Working Group Archaeoseismology of the European Seismological Commission (http://www.esc.bgs.ac.uk/). They express the belief that archaeoseismology will produce data suitable for quantitative estimations of the seismic hazard. This work definitively forms a good starting point for the current project.

In these publications the evolution towards a more multidisciplinary approach is apparent, although it is still rather limited only involving some disciplines. Our intent in the IGCP project is to intensify this trend of multidisciplinary investigations. In this respect we subscribe to the conclusions of the last work, i.e. (1) the increasing necessity to collect original field data by means of multidisciplinary investigations, especially during archaeological excavations; (2) an increasing effort to put archaeoseismological evidence within a seismotectonic framework (‘territorial approach’) and to quantify the traces of past earthquakes in order to obtain quantitative estimates of the parameters of the ancient earthquakes (see preface of Galadini et al. 2006a).

References


Galadini, F., Hinzen, K.-G. & Stiros, S. C. 2006a. Archaeoseismology at the Beginning of the 21st century. Journal of Seismology 10. This special issue reflects the increasing tendency towards multidisciplinary investigations on archaeological sites, as well as the convergence with respect to different archaeoseismological approaches. This work is the result of discussions within the framework of the Working Group Archaeoseismology of the European Seismological Commission (http://www.esc.bgs.ac.uk/). They express the belief that archaeoseismology will produce data suitable for quantitative estimations of the seismic hazard. This work definitively forms a good starting point for the current project.


4. Work plan (items by year)

The main activities within the framework of the proposed IGCP project are the field meetings in combination with the workshops/field schools. These meetings will be the ideal forum where the objectives of the project will be realised. These field meetings will be organised in different localities within the area of interest, i.e. the Alpine-Himalayan seismic zone. On the one hand, this will allow fostering and promoting archaeoseismological work by local scientists (i.e. ‘seed points’) and allowing young and emerging scientist form all relevant disciplines to participate to the general debate. On the other hand, the field meetings go to the heart of the project, i.e. bringing specialists of as many relevant disciplines as possible together ‘on site’ to confront ideas, evaluate the archaeoseismological evidence, eventually to create a common vocabulary and knowledge base and to pursue the development of workable archaeoseismological methodologies. Starting in the Mediterranean ‘cradle’ of archaeoseismology with the kick-off field meeting (Southwest Turkey), we intend to gradually ‘migrate’ to the east into ‘new territories’. These meetings will each time pay particular attention to gather as many interested scientists as possible from the region, allowing them to share their work with the international archaeoseismological community.

Associated with the field meetings workshops/field schools will be organised. These workshops aim at the knowledge transfer between disciplines and the establishment of a common knowledge base, an essential step towards a transparent discussion between specialists of different disciplines. These workshops are primarily aimed to young scientists of the host countries, training them in different aspects of earthquake geology and archaeology. Possible subjects of the workshops are: (1) Seismology: the physics of earthquakes; (2) Earthquake Engineering: basic principles of how buildings react to earthquakes; (3) Geomorphology: interpreting the ‘seismic landscape’; (4) Archaeology: interpreting destruction layers and damage patterns; (5) History/Anthropology: Earthquakes and history: how ancient civilisations recovered from earthquakes.

The closing scientific meeting will primarily make the synthesis of what has been achieved during the project and outline the framework of future research and initiatives.

Besides the proper initiatives taken within the framework of the proposed project, a close collaboration will be aimed for with the INQUA Subcommission Palaeoseismology and the ESC Working Group Archaeoseismology (and other similar initiatives and projects) to organise joint meetings and/or to support each other’s initiatives. Furthermore, initiatives will be taken to organise special sessions on international conferences, in the field of earth sciences (e.g. EGU, IGC, AGU); seismology (e.g. SSA); archaeology (e.g. WAC, ISA); hazards, etc, focusing on particular aspects of archaeoseismology or presenting the general state-of-the-art of the discipline, primarily promoting the visibility of the discipline and stimulating cross-disciplinary communication.

Finally, every opportunity will be seized to invest in science outreach, with respect to both local communities and authorities and an international audience (by means of newspapers, science magazines, documentaries and other public media).

2008

The main emphasis of the kick-off field meeting lies on objective 1 (see § 8.1). This meeting has the intention to set the stage for the next five years, outlining the state-of-the-art on archaeoseismology, focussing on the issues to be addressed, the research questions to be tackled, etc. Particular objectives are:
(1) to synthesize and review the state-of-the-art on archaeoseismology; (2) to confront the different methodological approaches, evaluating the pros and cons; (3) to explore the way towards workable standardized methodologies and to test this in the field; (4) to identify the issues to be addressed; (5) to identify and evaluate the reliability of the main diagnostic criteria for ancient earthquakes and to test them in the field; (6) to pursue the integration of archaeoseismological evidence and criteria in seismic intensity scales (e.g. INQUA ES2007); (7) to link archaeoseismological evidence and diagnostic criteria with physical earthquake parameters. The kick-off field meeting (and workshop/field school) is planned to be organised in **Southwest Turkey** (Eskişehir, Pamukkale, …) by the leaders of the project (E. Altunel, I. Stewart, T. Niemi, M. Sintubin). The field activities during this meeting concern the first ‘laboratory site’, i.e. the Eastern Mediterranean (see § 8.6). The theme of the field school has still to be determined.

A proposal has been submitted to organise a special session on **Archaeoseismological methodologies. Principles and practices** during the Seismological Society of America Annual Meeting, to be held in Santa Fe (U.S.A.) in the April 2008. Another proposal has been submitted to organise a special session on ‘Archaeoseismology: from archaeology to seismic-hazard assessment’ during the 33rd International Geological Congress, to be held in Oslo (Sweden) in the August 2008. Both proposals are not yet approved. If these session proposals are approved, both sessions will definitively serve to promote the proposed IGCP project. An active participation is, moreover, planned for the 13th Joint Geomorphological Meeting ‘Landscape Evolution and Geoarchaeology’ (Porto Heli, Greece, June 2008), where archaeoseismology is one of the central themes. This year, the archaeological community will be targeted by participating to the 37th International Symposium on Archeometry (ISA) (Siena, Italy, May 2008). In later years participation to the World Archaeological Congress (WAC) is envisaged to reach the archaeological community.

**2009**

In the second year of the project, emphasis will gradually shift from **objective 1** to **objective 2** (see § 8.1). The main objectives of the field activities will be (1) testing diagnostic criteria for ancient earthquakes; (2) testing workable standardized methodologies; (3) extending the archaeoseismological data base in a different geodynamic framework. The latter is achieved by focussing on new ‘laboratory sites’, i.e. the Dead Sea Transform region in the Middle East (see § 8.6) and the Western Mediterranean.

A field meeting is planned in the **Southern Dead Sea region** (Jordan, Palestine, Israel, Egypt), coordinated by project leader T. Niemi and co-workers (from Jordan and Israel). The organisation of this meeting will be tuned with a planned meeting in the same region by the INQUA Subcommission Palaeoseismology (late 2008 – 2009). A second field meeting is considered to be organised in the **Northern Dead Sea region** (Syria, Turkey). In both cases a field school (theme to be determined) will be organised.

In 2009 the INQUA Subcommission Palaeoseismology is planning to organise a workshop on archaeoseismology in **Southwest Spain** (organisers: P. Silva & K. Reicherter). We intend to collaborate with the organisers to integrate this workshop into the objectives of the IGCP project.

**2010**

In the third year a field meeting and field school will be organised in **Kyrgyzstan**, exploring a new ‘laboratory site’ (see § 8.6) in the hinterland of the Alpine-Himalayan collision zone. This meeting will be coordinated by A. Korjenkov (Institute of Seismology, Bishkek, Kyrgyzstan). The objectives of this meeting primarily comply with **objective 2** (see § 8.1), i.e. (1) testing diagnostic criteria for ancient earthquakes; (2) testing workable standardized methodologies; (3) extending the archaeoseismological data base in a different geodynamic framework. Particular attention will be paid to morphological expression of earthquakes in the landscape (in the framework of the field school).

**2011**

In the fourth year focus will again shift to a new ‘laboratory site’, i.e. the **Indian subcontinent** (see § 8.6). A field meeting is planned to be organised in India with the active contribution of colleagues working in the region (e.g. R. Kovach, C. Rajendran, J. Malik). The objectives of this meeting again comply with the **objective 2** (see § 8.1).

**2012**

In the final year of the project a **closing scientific meeting** will be organised by the leaders of the project, most probably in London (U.K.) or Leuven (Belgium). The objectives of this scientific meeting are (1) the synthesis and review of the advances made; (2) the presentation of workable standardised methodologies for archaeoseismology; (3) the exploration of future issues to be addressed.

In the same year a final field meeting is considered to be organised in the **Southeast Asia** (Indonesia, Japan, China, …), making the link with the traditions in earthquake archaeology in the Circum-Pacific and exploring the archaeoseismological potential of the Circum-Pacific.
5. Results expected

a) in basic sciences

The proposed project primarily focuses on contributing in the advancement of archaeoseismology as a scientific discipline with the purpose of further developing archaeoseismology as an independent and generally acknowledged scientific discipline.

Particular objectives are:

- reviewing the state-of-the-art on archaeoseismology (2008-2009)
- synthesizing and evaluating methodological approaches (2008-2009)
- inventorying diagnostic criteria from all disciplines involved (2008-2009)
- assessing and quantifying the reliability of archaeoseismological evidence (2009-2010)
- designing and testing a workable and standardised methodology for archaeoseismology (2008-2012)
- designing work strategies for excavator directors with respect to earthquake archaeology (2008-2012)
- creating a global knowledge base of archaeoseismological evidence (2008-2012)

The ultimate aim of the project is to make a substantial contribution to a better understanding of the earthquake history of a region (in particular the distribution of seismicity through time) by integrating archaeoseismology as a complementary source of data in the whole range of approaches (instrumental seismology, historical seismology, archaeoseismology, palaeoseismology, earthquake geology). By giving a quantitative assessment of the reliability of the archaeoseismological evidence and trying to translate this evidence in earthquake-related parameters, a significant contribution to seismic-hazard studies could be achieved. These ultimate objectives are long-term objectives to which this project is intended to make a substantial contribution, but which will most probably not be achieved in the 5-year period of the project.

b) in applied sciences and technology

With the elaboration of a global knowledge base of archaeoseismological evidence, as well as the quantitative assessment of the reliability of this evidence, the integration of archaeoseismology in seismic-hazard studies is pursued. This data base should not only include criteria diagnostic for earthquake-related damage, but also different typologies of anti-seismic design. Such a data base may, moreover, contribute to mitigation efforts of seismic risks during restoration and preservation of archaeological sites, in particular cultural heritage sites. This objective can also be considered as a long-term objective to which this project will contribute by creating such a data base.

c) in respect of benefit to society

The societal benefit of the project, on the one hand, emanates from the contribution of the project to further integrate archaeoseismology in seismic-hazard studies. On the other hand, the main societal benefit of the project will be the outreach to local communities and authorities in developing and emergent countries, boosting the public awareness with respect to earthquake hazard. Such awareness remains one of the key elements in the reduction of the risks.

6. Participation

a) Countries or institutions (or individuals) which have already agreed to co-operate

The following scientists have agreed to cooperate in the proposed IGCP Earthquake Archaeology Project and to form the nucleus of the group we want to build in the future (see Supplement 3 with the confirmation e-mails). The key practitioners of archaeoseismology all confirmed their interest and participation to the project. To reach its full potential as a truly interdisciplinary group, the leaders of the project intend to keep promoting the project, in particular to the archaeologists, historians and engineers.

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Amos Nur, 397 Panama Mall, 317 Mitchell, Stanford University, Stanford, CA 94305-2215,
b) Countries likely to participate

In the first place countries within the Alpine-Himalayan seismic zone may show an interest in the proposed project. Countries that are not yet represented in the list of participants with a formal commitment are: Morocco, Algeria, Tunisia, Libya, Egypt, Iran, Iraq, Pakistan, Afghanistan, China, etc.

Secondly, countries outside the Alpine-Himalayan seismic zone but confronted with a serious seismic hazard may show an interest. These countries are primarily situated around the Pacific: Indonesia, Philippines, New Zealand, Taiwan, Japan, Korea, Russia, Canada, Mexico, Peru, Bolivia, Ecuador, etc.

A series of scientists have been contacted but have not yet confirmed their participation:

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The objectives of the proposed IGCP project have affinities with some of ongoing IGCP projects. Once the project is approved, contact will be taken with the leaders of these projects to see where complementary interest is possible.

5. IGCP 526 ‘Risk Resources and Record of the Past on the Continental Shelf’ (Chiocci L., Collings, L., Michaelovitch de Mahiques M., Hetherington, R. – 2007-2011)

As already mentioned, an intense collaboration will be pursued with the INQUA Subcommission Palaeoseismology and the ESC Working Group Archaeoseismology, creating a common platform where activities in the field of archaeoseismology and related issues are coordinated.

7. Location of major field activities

The Alpine-Himalayan seismic zone is seismically one of the most active regions in the world, and at the same time one of the most populated regions of the world (see images taken from the UGS website [http://earthquake.usgs.gov](http://earthquake.usgs.gov) illustrating the seismicity of the last decade (1990-2000)). The seismic activity is the direct result of the ongoing convergence and collision of the African, Arabian and Indian-Australian tectonic plates with the Eurasian plate. This convergence and collision occurs in a predominant continental setting, causing very complex geodynamics. This results in a wide region of seismicity extending far into the Eurasian continent, as well as in a relatively ‘shallow’ (less than 35 km) seismicity, a setting which can be considered highly hazardous. The Alpine-Himalayan belt extends from the Strait of Gibraltar in the west to Southeast Asia (Indochina & Indonesia), a land corridor that comprises the entire Mediterranean region, the Middle East, Persia, Central Asia, the Indian subcontinent and Southeast Asia. Significantly, seismic activity along much of this belt is distributed across an often diffuse network of fault lines, individual segments of which typically rupture every few centuries to millennia. Such long recurrence intervals make this region ideally suited to archaeoseismology, and hence this is identified as the natural laboratory for cultural sites that will allow us to achieve the objectives of the proposed IGCP project.
Potential ‘laboratory sites’

- **Eastern Mediterranean** (Turkey, Greece): The Eastern Mediterranean can be considered one of the ‘cradles’ of archaeoseismology, with roots that extend back to the pioneering work of Arthur Evans, Heinrich Schliemann and Claude Schaeffer. In recent decades, however, extensive archaeoseismological work has been performed in this region, largely under the auspices of geological investigations of long-term seismic hazard. In this respect this ‘laboratory site’ is the ideal environment to pursue objective 1 of the proposed project (see § 8.1), reviewing the state-of-the-art of archaeoseismology. In particular **Southwest Turkey** is selected, because extensive archaeoseismological work has been done recently on different archaeological sites (Hierapolis, Knidos, Sagalassos, Priene, Ysa, Tralles,…), primarily in a geodynamic context of crustal extension (normal faulting environment). The kick-off field meeting (see §8.4) will be organised in Southwest Turkey.

- **Dead Sea Transform** (North and South): In the Middle East much seismic-hazard research has been focused on the Dead Sea Transform, a continental strike-slip fault that constitutes a plate boundary. The southern part of the transform appears the more seismically active in recent centuries and consequently has been subject to considerable geological investigations and has a long legacy of geoarchaeological work (including interest of earthquakes in the biblical narratives). In contrast, the northern part of the transform has been seismically quiet for recent centuries, and is interpreted by many as a prominent ‘seismic gap’ where a major future earthquake could be building. Historical records and emerging archaeoseismological evidence support the view that this northern strand hosts very large seismic events, ensuring that its enigmatic region has a high hazard potential. The contrasting seismotectonic behaviour of the northern and southern strands is intriguing, and detailed archaeoseismological and palaeoseismological work is needed to generate crucial information to better understand the long-term seismic cycle. Because the archaeological expression of the northern and southern parts is very different, the project proposes field meetings in both regions (see §8.4). One meeting will be held in the south, and draw together from scientists from Jordan, Palestine, Israel and Egypt, whilst a second meeting will be held in the north (Syria) and integrates scientists from Turkey, Syria, the Lebanon and neighbouring countries.

- **Persia** (Iran, Iraq): There is a strong impetus in this region because of the Bam 2003 earthquake destroying an UNESCO World Cultural Heritage Site. There is furthermore a clear relationship between sites of ancient agriculture and active faults, because active earthquake zones seem to generate ideal natural environments for human occupation (Jackson 2006), eventually causing a serious seismic hazard issue of major cities, such as Tehran. The project would very much like to prepare a field meeting and workshop in Iran and will work to this end, involving scientists with specific expertise in this region. However, because of the safety and political situation, any initiative in this region is highly conditional.

- **Central Asia** (Kyrghyzstan, Kazakhstan, Armenia,…): This hinterland of the Alpine-Himalayan collision zone is the region of the northern branches of the Great Silk Route. Along these routes small caravansarays, as well as significant cities such as Balasogon (capital of medieval Karakhanids Khanate, destroyed by an earthquake in 1475). This region has also been the scene of the westward migration of the Huns and Chinghishkan. Notwithstanding all destructions to the ancient cities in Central Asia are attributed to these “barbarous” invaders, archaeoseismological evidence in Akyrtash, Antonovka, Talgar (Kazakhstan) and Kamenka (Kyrghyzstan) reveal a seismic origin of the destruction. This region is of particular interest with respect to objective 2 of the proposed project (see § 8.1). A field meeting will be organised in Kyrgyzstan focusing on the archaeoseismological evidence in Kamenka and the morphotectonics in the wider surroundings.

- **Indian subcontinent** (India, Pakistan, Afghanistan): This region is home of ancient cultures such as the Bronze age Indus Valley or Harappan civilisation (extending from Pakistan, western India, parts of Afghanistan and Turkmenistan). Archaeoseismological work is still in its infancy in this region. A planned
field meeting aims at intensifying this research and to put this research into an international context (see objective 2 - § 8.1).

Besides these main 'laboratory sites' on which the proposed IGCP Earthquake Archaeology Project is focused, other regions within the Alpine-Himalayan seismic zone are certainly not excluded. When the occasion presents itself, other regions may become 'laboratory sites'. In particular the following regions are considered:

- **Northern Africa** (Morocco, Algeria, Tunisia, Libya, Egypt) and the **Western Mediterranean** (Italy, Spain): the westernmost extension of the Alpine seismic zone. While the Western Mediterranean is also a traditional study area for archaeoseismologists (see § 8.4, planned INQUA workshop in Southwest Spain), Northern Africa can be considered new territory for archaeoseismological research.
- **Tibetan Plateau** (China, Tibet): the hinterland of the Himalayan collision zone.
- **Southeast Asia** (Burma, Laos, Thailand, Indonesia, ...): This easternmost extremity of the Alpine-Himalayan seismic zone allows to link with the circum-Pacific.

**References**