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PROJECT APPLICATION

The deadline for receipt of applications by the Secretary-General and the President of the sponsoring Commission is **January 31st of the year in which funding is requested**. Please read the funding guidelines on the INQUA webpage before completing this document. We encourage you to consult the appropriate Commission President at an early stage in the development of your proposal or if you have any queries about eligibility. Please enter information in the allocated boxes, taking note of the length restrictions, and add rows to tables as required.

DETAILS

1. Year of application

2016

2. Name of primary Commission supporting your proposal

TERPRO: Terrestrial Processes, Deposits and History

3. Name of International Focus Group supporting your proposal

EARTHQUAKE GEOLOGY AND SEISMIC HAZARDS (EGSHaz)

4. Project title

SURface FAulting Catalogue – Earthquakes (SURFACE)

5. Leader(s) (All communications will take place by email unless specifically requested otherwise, in which case a fax number should be supplied.)

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6. Confirmed international participation. Please give name and affiliation, and indicate if the participant is a graduate student (PhD), early-career researcher (ECR), developing-country researcher (DCR) or senior scientist (SS), using the table below). Please add rows to this table as necessary!

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(PhD, ECR, DCR, SS)

7. Proposed overall duration (years or inter-congress period)

INTERCONGRESS PERIOD 2016 – 2019

DESCRIPTION

1. General description. Please describe the background and long-term goals of the project in terms accessible to a non-specialist. If the application is successful, this paragraph will be used by the sponsoring Commission to advertise your activity on the website.

During the previous inter-congress period, the INQUA Project 1229 produced a database of pre-historical and historical earthquakes and their associated on-fault and off-fault effects on the natural environment. The proposal presented for the next inter-congress period 2015-2019 focuses on one of the coseismic effects, that is the surface faulting, i.e. permanent ground displacement occurring with the seismic activity of faults.

The catastrophic earthquakes in the last decade reminded to society and also to scientists that Quaternary active faults may cause severe damage, associated with seismic shaking, tectonic surface ruptures or secondary effects. For several of these events, the source fault was completely unknown before the earthquake (e.g. Bam, Iran, 2003; Darfield, New Zealand, 2010) but, in most of the cases, the seismic potential of the fault was largely underestimated (Sichuan, 2008; Kashmir, 2005; Haiti, 2010; Tohoku, 2011). Whatever the case, the outcome was an intense and interesting debate (e.g. Stein et al., 2012), on the contribution of geological and paleoseismic data in the future seismic hazard assessments (SHA). The recent earthquakes demonstrated that the "pre-historical" information is crucial to assess with reliability the seismic hazard. This is particularly true in regions at low earthquake probability levels (e.g. so-called "intraplate" regions), because they enlarge the time-window in which seismic activity can be properly analyzed. Outstanding example is the "Central and Eastern United States Seismic Source Characterization" performed for the nuclear facilities (EPRI et al., 2012). In more active areas, the paleoseismic information also feeds fault models (UCERF3: Field et al., 2013) used in seismic shaking hazard maps (Petersen et al., 2014) or allows defining avoidance buffers against fault rupture before building (Kerr et al., 2003). This issue is definitively required for nuclear safety. In this line, the case of the Japanese nuclear industry is notable, because plant operation is sometimes suspended to Quaternary geological data and their interpretation (Chapman et al., 2014). On the other hand, the past decade also severely recall that even moderate-magnitude earthquakes ($M_w<6.5$) can cause dramatic casualties and/or losses for the economy and the society (e.g. L'Aquila, 2009; Christchurch, 2010; Lorca, 2011; Napa, 2014). One of the big challenges is the recognition of the earthquakes' sources which are relatively small, slow and low slip, and which can leave subtle, non-diagnostic (or no geomorphic) evidences, but where paleoseismic evidences eventually account for prehistoric ruptures related to large earthquakes ($M_w > 6.5$). This difficult task can now find a valid support by the recent advances in remote sensing techniques, which allow the detection of subtle fault morphologies (Light Detection And Ranging-LiDAR) and tenuous coseismic displacements (Interferometric Synthetic Aperture Radar-InSAR). This progress certainly improves our ability in the recognition of surface faults, especially the ones with low amplitude ground deformation, leading to new perspectives for the geological input on the SHA. Accordingly, it becomes necessary to target testing examples to critically analyze how much or in which way these innovative techniques can provide diagnostic or complementary signals on seismogenic sources which could usually be missed using the traditional techniques of terrain analysis.

In the framework of the proposal, we therefore suggest starting a project that emphasizes geomorphology and tectonic landform investigation as a tool for 1) improving the capability of the recognition of Quaternary capable faults, i.e. structures showing potential for displacement and/or deformation at or near the ground surface, which is of interest to INQUA. A direct consequence is 2) a major awareness of the relation between surface faulting produced by earthquakes vs earthquake sizes and earthquake fault parameters, which is of interest to earthquake geologists and engineers. The new project will also aim at 3) upgrading the existing EEE database, especially for fault displacement datasets that would contribute to the Probabilistic Fault Displacement Hazard techniques (PFDHA). Note that the International Atomic Energy Agency (IAEA) is developing a working group focused on this topic.

All the tasks will be coordinated in different working groups, incorporating Quaternary geologists, geomorphologists, geophysicists, structural geologists, engineers, archaeologists and soil scientists.

2. **Justification for project.** Please provide a justification of the need for the project. Please identify the benefits of this activity, both for individuals involved and the wider INQUA community.

The proposed project is in line with the previous Project#1299 of the PALACTE Focus Group, which included successively the ratification of the ESI-07 Intensity Scale (2007 INQUA Congress), the generation of the on-line EEE Catalogue (almost 100 events), and finally the parameterization of the ESI-07 intensity with other source parameters. This FG ends in 2015 and we call for the creation of a new Focus Group (SURFACE – SURface Faulting CataloguE) which will be dedicated to the updating, upgrading and development of a worldwide surface rupture database.

In SHA, a great deal is the recognition of surface faults which are capable to generate ground displacement and seismic motion. The detection threshold of the surface expression of individual earthquake has long been around M=6.5±0.5 because lower magnitude earthquakes, often generate faint, short and discontinuous ground ruptures and/or distributed deformations, which could have been only overlooked during past post-seismic surveys. Because of the technological evolution, the study of the small coseismic deformation can be now envisaged and completed successfully. Besides, the new techniques also enable the identification of moderate cumulative surface offsets. One of the goals of the project is to fill this gap of knowledge. Note that, if this clearly applies to moderate-size and shallow crustal faults, this clearly also applies to large blind or highly segmented faults which can generate large earthquakes (e.g. 1906 Manas earthquake, China, Stockmeyer et al., 2014). In order to correctly estimate the associated SHA, and especially the surface displacement hazard, there is a need for an improvement of the fault map accuracy, through high resolution geomorphic analyses and focused remote sensing techniques (target of task 1). PFDHA requires the knowledge of functions describing the likelihood of surface faulting as a function of Mw (target of task 2). Such functions have been proposed in literature, but these need to be updated with modern data and more cases. Finally, the PFDHA requires worldwide displacement data to obtain regression curves of displacement with distance, both along and off the master earthquake fault. This task (3) is crucial, because the statistics of on- and off-fault deformations is now insufficient: today, the published databases with primary and secondary evidences of faulting are scarce and scattered (13 normal fault events in Youngs et al., 2003; 9 strike-slip fault events in Petersen et al., 2011, to which we can add the 17 Japanese cases of Takao et al., 2013). In addition, the comprehensive dataset should include the triggered fault traces, which is not the case up to now. In this line, improved methodology for the study of Quaternary landscape evolution is a key tool, because the cumulative evidence for primary and secondary earthquake fault displacement is preserved in the stratigraphy and landforms of the epicentral area.

Several participants of the project have been involved in an Expert WG of the IAEA-ISSC devoted to elaborate a technical document (TECDOC) providing advice and guidelines on the recognition, analysis, dating and parametrization of the EEE from investigations of historical seismicity and paleoseismicity, and their application in SHA for nuclear facilities. This effort represented a major transfer of Quaternary scientific knowledge and methodology towards the societal needs of a safe siting and design of critical facilities. The document has been published by IAEA in 2015 (IAEA TECDOC 1767). This joined activity represents a relevant phase of the INQUA Project, which is expected to result in promotion and increasing of researches on paleoseismology and Quaternary geology.

In 2015, a new work plan of the Extra Budgetary Program of the ISSC-IAEA has been endorsed for future actions and one is specifically devoted to the fault displacement hazard assessment based on statistical analysis of primary and secondary fault displacement (PFDHA) at a specific site. This is in complete agreement with the project here presented because the IAEA-ISSC working group will first focus on gathering and homogenizing this existing earthquake surface faulting datasets. The proposed INQUA project will be again an outstanding effort and support of scientific community to societal needs.

Another duty will be encouraging the implementation of surface rupture data of very recent earthquakes, in order to upgrade and augment the existing databases. The INQUA, with its worldwide audience, is the relevant framework to encourage the earthquake scientists in constituting and maintaining such a global and homogenous catalogue.

Scientists directly involved in the project will benefit from the information exchange facilitated by the framework of future (recently done, planned or in discussion) workshops held in different continents (Americas: USA; Europe: France, Greece; Asia: Japan; Oceania: New Zealand) enhancing the regional participation. This benefit was already tested in the last project workshops held in Morelia (Mexico, 2012), Aachen (Germany, 2013), Busan (Korea, 2014) and Fucino (Italy, 2015). Also the activities of the project facilitate several editorial platforms that can host the studies of the participants**,** favoring those led by young scientists. In 2014, the Focus Group had four running editorial projects in peer-reviewed indexed journals (such as Geomorphology, Ann. Geophysics, Z.F. Geomorph., Quaternary Int.). Additional relevant effort is focused to facilitate on-line information exchange through several web pages hosted in ISPRA, AEQUA and INQUA, but mainly our matrix paleoseismicity.org (blogs, news, announcements, forums), Facebook and Twitter. In this way, the on-line EEE-Catalogue provides to the participants the opportunity of consulting, compiling and analyzing the EEE in a semi-quantitative way, as well as to proceed for individual new data uploads in the public interface of the web-page. In the near future, we plan to extend these opportunities to the quantitative “surface faulting” database.

Regarding to the benefits to the wider INQUA community, the project activity will provide a large amount of reviewed information by means of the aforementioned and future publications on paleoseismology and archaeoseismology, but also on Quaternary Geology itself, facilitating the collaboration of specialists of different branches of Quaternary Science. In addition, the themes proposed for the continuation in the 2016-2019 period will emphasize the cooperation with geophysical techniques and methods. These will clearly contribute to improve the application of Quaternary Geology in SHA.

3. Specific objectives. Please list the proposed concrete outcomes of the project.

We summarize hereafter the main actions and outcomes.

Geomorphic techniques applied to capable fault studies: improvements from the remote sensing tools

We will proceed with the investigation of the geomorphic imprint of active faults by the means of modern remote sensing techniques, among them the LiDAR and the InSAR.

High-resolution LiDAR DEMs offer a new possibility to recognize, map, and interpret subtle indirect indicators of recent tectonic activity, like drainage network deflection or surface warping. Coupled with appropriate tools, the numerical topographic models can help also in guiding the field reconnaissance of surface faulting after an earthquake (e.g. Shinagawa et al., 2014; Cronin et al., 2008), as well as identifying subtle surface displacements due to earthquakes (e.g. Oskin et al., 2012: El Mayor earthquake, Mexico, 2010; Hudnut et al., 2014: Napa earthquake, 2014). A next phase of applying LiDAR to active faulting is to target blind active faults.

For moderate earthquakes able to generate centimeter-scale offsets, InSAR techniques can also be valuable because they can rapidly provide a location and a rough amount of surface displacement (e.g. Dawson et al., 2008, JGR, for earthquakes of M4 to 5). InSAR has also been a successful method to highlight small surface displacements at large distances of large earthquakes: a nice example is the El Mayor earthquake, 2010, Mw=7.2 for which field reconnaissance (Rymer et al., 2011) and remote sensing analyses (Wei et al., 2011) yielded complementary faulting patterns in SW USA. Another interesting case is the Napa earthquake (2014) for which the surface rupture has been extensively mapped thanks to InSAR, LiDAR and SfM (Structure from Motion) techniques (Hudnut et al., 2014; Brocher et al., 2015).

This effort should not avoid providing the limitation of the methods, based on a critical analysis of how far one can push these technologies. As an international community, we will take advantage of a rich database of cases.

One of the first tasks will be devoted to identify field testing examples, in different morphotectonic/morphoclimatic settings. The results of the actions will concern these case studies using identified techniques and will consist of methodological notes. All this can be diffused and discussed by the scientific community during the next INQUA meetings or sessions organized by the Focus Group.

New insights on the empirical scaling relationships: completing the surface faulting database towards the moderate earthquake magnitudes

Recently, Stirling et al. (2013) published a compilation, classification and ranking of existing relationships between magnitude and fault parameters. Based on newly published, compiled or acquired data (including with remote sensing techniques; see task 1), we aim at proposing complementary catalogues of surface ruptures which may result in the edition of new/updated relationships between quantitative values of surface deformation (i.e. rupture length, displacement, slip rates, etc.), seismological parameters and eventually local geological conditions. We will focus on the moderate range of earthquakes (M<6.5) to carefully infer what is the real lower boundary of magnitude for surface rupturing. Indeed, several worldwide examples illustrated that surface rupture can occur at low magnitudes and with peculiar characteristics: see for example the centimeter-scale offset reported for the M3.6 earthquake in California in March, 4th, 1966 (Brune and Allen, 1967), or the decimeter-scale surface deformation formed during the recent Enarbella M 5.4 earthquake in Australia (Clark et al., 2014, BSSA). In order to isolate the factors responsible for this variability in surface rupture in the M4.5 to M6.5 earthquakes, we really need to increase the number of such earthquakes in our data set, beyond Wells and Coppersmith (1994) and later publications focusing on the high magnitude part of the scaling relationships (e.g. Hanks and Bakun, 2008). We will act on the revision of the on-land earthquakes after 1993 (time limit of Wells and Coppersmith dataset) in moderate magnitude range, analyzing the known geology of the epicentral area, and trying to figure out what are the factors controlling the threshold of surface rupture. Most of the cases will not report surface rupture in the published literature and, if the provided information is complete, this could be interpreted as “negative data”. Understanding the reasons behind the lack of surface rupturing is equally important. In the case of a large collection of moderate earthquakes data, we will create sub-datasets to test hypotheses accounting for different fault kinematics (normal, reverse, strike-slip) and local geology (e.g. thick or thin cover of Quaternary deposits, age of the sediment or any relevant parameter). If needed, we can expand the target to those cases where the threshold morphogenic earthquake could be larger than M7 (i.e. strong destructive earthquakes without surface rupture), like for example in Argentina (Sierras Pampeanas) where historic strong (Mw≈7) and shallow (<12 km depth) earthquakes did not rupture the surface whereas paleoseismology suggests that vertical slip larger than 1m occurred during the Holocene in the area (Costa, 2015).

The concrete outcome from these actions will be an updated scaling relationship between magnitude and surface rupture parameters. We will provide complementary geological info on the factors locally controlling fault ruptures, which will help to a better understanding on the variability depicted by empirical laws.

<u>Surface faulting catalogue:</u> collection of the quantitative information on surface faulting (including negative evidence) for recent and historical earthquakes.

We will refer to and complete the existing EEE catalogue project (which is permanently updated). It is important to compile the measurements of surface deformation after earthquakes in the same form, both on- and off-fault (or distributed = secondary or triggered). Dealing with surface deformation due to earthquake, an important topic for many regions –especially intraplate with low activity- is to account for the local site conditions. It is now recognized that sub-superficial geology and hydrogeological conditions largely affect the pattern and amount of surface faulting (e.g. Moss et al. 2

013, SRL; Fletcher et al., 2014, Field Trip Guide Friends of the Pleistocene) and these have to be considered now in future analyses. The project will encourage the studies on surface faulting measurements of reverse earthquake fault. Currently, normal faults (Hanks et al, 2003) and strike-slip faults (Petersen et al, 2011) have scarce primary/distributed databases; which is not even the case for reverse faults yet. In addition, an important database has been compiled in Japan (Takao et al., 2012).

For historical events, an interesting point should be to link this geological database with the seismological GCMT (Global Centroid Moment Tensor) and geodetical ICMT (InSAR CMT; see Weston et al. 2012 for information) which provide crucial earthquake fault parameters (depth, geometry, slip distribution, etc). Another catalogue to be considered is the "finite-source rupture model database" (Paul Martin Mai, equake-rc.info/SRCMOD/) which already includes 145 earthquakes at May 2014.

The concrete outcome is a georefenced database of historical and recent earthquake surface rupture with detailed information on fault segment map, displacement measurement, type of soil.

Networking: Developing a network of national (or regional) referring earthquake geologists

The aim is to build a network of earthquake geologists (by country or region) with the role of gathering the relevant existing data for completion of the database of surface faulting. These geologists should also facilitate the field work (logistics, contacts, info exchange) in case of future earthquake surface ruptures to be surveyed.

4. **Fit to remit of sponsoring Commission.** Please explain how the proposed project will enhance the activities of the sponsoring Commission and specifically how it contributes to the goals of the sponsoring IFG. Please explain how the IFG and the project will communicate and interact.

Paleoseismological research is linked to the activities of INQUA since more than three decades when there was the old independent INQUA Neotectonics Commission. After the reorganization of INQUA in 2003, paleoseismology was included as a working group in TERPRO (Commission on Terrestrial Processes, Deposits, and History), afterwards converted in a new Int. Focus Group since 2007. The activity of this INQUA paleoseismological community has been really fruitful under the direction of Alessandro Michetti (2003-2011), and always based on the analysis of the past seismicity by means of a thoughtful and comprehensive analysis of the Quaternary Geology and Geomorphology. In the next stage (2016-2019), the activity of the IFG will be focused on i) adapting the "primary and secondary earthquake environmental effects (EEE) database" to a quantitative database of coseismic surface faulting and deformation due to earthquakes, ii) integrating new data to set updated scaling relationships between magnitude and geologically measured deformation, and iii) promoting geomorphic studies involving modern techniques. These are targets fully fitting with the Quaternary geosciences.

The large set of stratigraphic and geochronologic data generated by paleoseismological research conducted in a vast variety of environments, from wetlands to semiarid regions and glaciated mountains, constitutes a relevant feedback for the understanding of the terrestrial processes, and of the evolution of landscape and of active tectonic areas mainly during Late Quaternary and Holocene times. As stated in the TERPRO WEB site the sponsoring commission promotes research on Quaternary terrestrial environments and history, "especially in those areas that investigate new frontiers in science and incorporate multiple and cross-disciplinary research efforts, multi-national research and involve developing countries". In this sense the proposed INQUA Project promotes geomorphological, paleoseismological and neotectonic research in order to get quantitative information of historical and pre-historical earthquakes, which really constitutes a difficult task placed in the frontier of the present scientific knowledge. The consecution of this complex objective requires the collaboration of a large variety of scientist not only related to the Quaternary science, but also to disciplines related to the Physics of the Earth, the Civil Engineering or to the Remote Sensing and Geodesy. This need ensures a fruitful interaction between the members of the Project with scientists involved in the TERPRO tasks. Although the IFG and the related project is placed in TERPRO, "Paleoseismology and Quaternary Tectonics" are certainly a transverse science developing multiple branches of collaboration with other IFG and INQUA Commissions (i.e. Marine processes, Geochronology) and promoting the role of the Quaternary Geology among scientists from different countries, including developing regions. As occurred in 2012 the activities in Mexico disseminated the EEE analyses to a wide variety of scientist of Central and South America. In 2013, the workshop held in Germany attracted the attention of many researchers of Central and East Europe. In summer 2014, our activities moved to East Asia (Busan, Korea) with the attendance of researchers of the Asiatic region (e.g. Philippines, China, Indonesia and India) where moderate to large seismic events are common. Finally, the Fucino meeting in Italy (2015) was attended by numerous researchers from Europe, which is concerned by moderate earthquakes.

In the following years, meetings will possibly take place in America (2016 in the USA), in Oceania (2017 in New Zealand) and in Europe again (2018 in Greece).

5. **Detailed description of activity.** Please give details of the proposed activity (or activities) including type of activity, where/when it will be carried out and who will be involved. Please identify (by name if possible) any people who will be funded by INQUA to participate in the activity. Please ensure that you describe BOTH the activities during the life of the activity and the specific things planned for the current year.

The proposed activities are split into 3 tasks. The general idea is to acquire, compile and analyze the quantitative data on coseismic surface faulting and deformation. The tasks address different issues that, at the end, are intimately interlinked.

Task 1. Geomorphology in Active Tectonics

1st phase: Test the limits of new remote sensing tools, data sets (e.g. DEMs), visualization software, and analytical software for identifying and measuring Quaternary tectonic deformation in the selected testing sites/structures. This will be an expanding field of study in the next decade.

2nd phase:

- Develop the use of LiDAR: Geomorphology-related projects would build on the increasing use of new tools such as LiDAR for identifying Quaternary and/or coseismic deformation on the land surface; also new offshore techniques may help in mapping subaqueous faults.
- Include the InSAR techniques to locate the overall deformation field, the primary and distributed deformation traces after an earthquake. In theory, these techniques can detect centimeter-scale offsets and have been applied to large events at large distances (e.g. Fukushima et al., 2013; Wei et al., 2011) and it can be applied to moderate earthquake ($5.5<M<6.5$) at short distances from hypocenter (e.g. Australia, Napa in California).

3rd phase: Apply LiDAR to blind or nearly-blind active faults. We begin to use LiDAR DEMs to look for subtle indirect geomorphic indicators of surface deformation. Of course, we will find fault scarps if they exist, but we also need to look for more subtle geomorphic features that indicate slow (or small) vertical or horizontal deformation of the ground surface. Considerable literature is available on the effects of vertical deformation on drainage networks and channel patterns. In areas of uplift the drainage pattern is "pushed away" or deflected around the uplift area, even in very low-relief areas covered by Quaternary sediments, in a way that cannot be explained by the bedrock geology or surficial geology (e.g. Burrato et al., 2003; Livio et al., 2009; Gunderson et al., 2013; 2014; Ponza et al., 2010; Michetti et al., 2012; Emergeo WG, 2013). Stream channels crossing the uplifting areas will downcut, straighten their channels, and steepen their gradients; the reverse will happen in areas of active downwarping. High-resolution LiDAR DEMs offer a new possibility to recognize, map, and interpret such subtle indirect indicators of active tectonics, which usually could not be detected by stereo air photos, or by large-pixel DEMs (10-30 m), or even by the "standard" 2-3 m-pixels LiDAR DEMs.

- Leader: Jim McCalpin

- Others: Alessandro Michetti, Francesca R. Cinti, Stéphane Baize

Task 2. Relationship between magnitude and surface deformation

- The threshold for the recognition of active faults has become critical in Probabilistic Seismic Hazard Assessment.

- 2016-2017: We plan to search for the recent on-land earthquakes with moderate magnitudes (below 6.5) and shallow focal depths, from existing catalogues (including EEE catalogue), publications, and eventually original research performed in the framework of this project. We then select those producing fault surface rupture for further implementation and analysis in the surface rupture database. Then, we should be able to plot the percentage of earthquakes that produced surface rupture against their magnitude. This empirical way will help in defining the magnitude threshold for morphogenic earthquakes. We proceed with the analysis differentiating extensional, compressional, and strike-slip regimes, using the latest published data. Examples may include for instance normal faulting earthquakes in Italy (e.g. Colfiorito 1997, L'Aquila 2009), reverse faulting in Australia (e.g. Ernabella, 2012), or strike-slip earthquakes (e.g. Napa, 2014).

- 2018-2019: We also need in this compilation to account for the local geology, especially for the ruptures that barely made it to the ground surface. For large earthquakes (M>7.5), the surface rupture trace is going to look very similar whatever is the shallow portions of the crust for most cases, except those with specific mechanical and geometrical patterns (flat and ramp systems in fold-and-thrust belts like Sierras Pampeanas of Argentina, Himalayan Ranges). In contrast, for M<6.5 earthquakes, the thickness of the superficial deposits and their rheology have a critical role in the propagation of the rupture up to the surface, as well as the structural characteristics of the source close to the surface (i.e. concentrated vs distributed faulting ; fold-related faults such as bending-moment or flexural-slip, basement fracturation). Rheology includes the moisture of the sediment and where the groundwater table is. Also, the presence of thick sequences of evaporitic rocks, or the existence of large gravitational deformations in mountain areas, might be able to promote the occurrence of earthquake surface faulting with unexpectedly high amount of surface displacement and rupture length for a given magnitude. It is aimed to analyze and compare examples from different tectonic and geologic frameworks as well.

- According to the published probability of surface rupture versus magnitude relationships, only 20% of M5.5 and 10% of M5 earthquakes would result in surface rupture (e.g. Pezzopane and Dawson, 1996). The big question is "why 80% of M5.5 earthquakes did not rupture the surface?" Besides the surface deposit thickness and rheology, there may be other factors at work. For example, one can expect that of the 20% of M5.5 events that ruptured the surface, most are normal faults and very few are reverse faults. Therefore, this would indicate that the threshold for morphogenic earthquakes is lower for normal earthquakes than for reverse earthquakes. This a priori statement needs to be supported with data. This is another aim of this task.

- <u>Leader: Koji Okumura</u>

- Others: Jim McCalpin, Alessandro Michetti, Carlos Costa

<u>Task 3. Secondary and distributed deformation</u>

- During the literature review related to the previous topic, we will also pay attention to the possible occurrence of secondary or off-fault deformation during recent earthquakes.

- <u>2016-2017</u>: First of all, the new project will try to collect and then merge the databases existing in the USA and in Japan (Youngs et al., 2003; Wesnousky, 2008; Petersen et al., 2011; Moss and Ross, 2011; Takao, 2013) into (an) homogenous file(s) of historical surface ruptures (primary and distributed evidences), including the quantitative values of offset (a continuation of the EEE database). The built database will represent a data source for the developing probabilistic method for surface faulting assessment (PFDHA). This part of the work will be supported by the referring partners identified in the various countries involved, to provide the appropriate datasets from their countries. A connection with the IAEA-ISSC working group on the same topic is expected.

- <u>2018-2019</u>: This gathering and implementation work will account for local geological condition (soil, saturated sediments, rock), because the surface faulting pattern (including fault dip, offset, etc) is largely influenced by surface geology. This second phase will focus on this aspect. Eventually, the statistical analysis of the datasets will lead to updated empirical regression curves between distance and displacement for relevant magnitude bins. External-to-INQUA experts could be involved (Mark Petersen, USGS; Tim Dawson, CGS; M Takao, TEPCO).

- <u>Leader: Stéphane Baize</u>

- Others: Oona Scotti, Francesca R. Cinti, Franck Audemard

6. **Workshop/meetings (**dates and venues if known).

The work plan will be completed during regular workshops/meetings between the leaders and co-leaders of the 3 tasks, eventually during field sessions on emblematic fault cases.

Here are some suggestions. The second is in discussion with Californian colleagues. The third meeting will be held in cooperation with New Zealand teams organizing the tri-centennial anniversary workshop (R. Langridge, GNS). The fourth will be organized in cooperation with IRD (Laurence Audin), in Ecuador/Peru.

- 2016
- Meeting of the leaders and co-leaders of the different tasks (PATA Days, Colorado); contribution from PhD Students and ECR from different countries; field trip to normal faults
- Project/business Meeting in Western USA – in discussion

- 2017
- Project Meeting in New-Zealand; field trip to strike-slip faults

- 2018
- PATA Days Workshop in Greece
- Project Meeting in Central Andes (Ecuador/Peru); field trip to active folds and faults (strike-slip/normal)

- 2019: Project Meeting – to be discussed

Preliminary and final results will be presented during PATA Days meetings of the Focus Group.

7. **Inclusivity plan.** Please give details of how the project will promote its activities, and seek to involve, e.g., early-career scientists and scientists working in low-GDP countries.

The project will promote its activities on-line, through web pages hosted in several Research Institutions of different countries, besides the page of INQUA. Our specific transmission tools are also paleoseismicity.org (blogs, news, announcements, forums), and other main social networks (e.g. Facebook, Twitter). The on-line Catalogue will be available to the participants not only for the consultation in the public interface of the web-page, but also for the uploading of new data. In this way, the web platforms will work as data sharing, knowledge exchange and dialogue. The annual or bi-annual workshops will encourage and sponsor the participation of young students and early-career scientists from all the countries, with priority for the developing countries. They will also ensure the cross-countries dissemination of the earthquake geology issues.

8. **Anticipated scientific results.** Please list the anticipated scientific outcomes of the project.

- Publication of studies on specific earthquakes, involving remote sensing techniques
- Implementation of a georeferenced database of historical recent earthquakes with detailed information on fault segment map, displacement values, type of soil
- Updating of empirical relationships between magnitude and fault/geological parameters
- Regression relationships of displacement with distance
- Formulation of probability of surface rupture vs M

9. Concrete outcomes. Please specify the likely concrete outcomes of the proposed activity.

- Schedule

2016

- Project Tasks Leaders' Meeting Report after PATA Days, Colorado
- Publications of relevant contributions to PATA Days
- Project Meeting Report in Western USA

- Preliminary framework of the surface rupture database; based on the existing ones, and gathering of the raw data for further statistical processing

2017

- Report after the New Zealand Project Meeting and publication of the relevant presentations given to the Coordinated session with NZ Workshop dedicated to Tri-centennial Earthquake on the Alpine fault
- Preliminary proposition of fault and environment parameters to be included in scaling regressions and, probably, in the statistical processing for displacement-vs-distance regression

2018

- Report after the Central Andes Project Meeting
- Consolidation of the database and first set of statistical analyses including probability of rupture vs magnitude; updated scaling relationships (M vs fault parameters); regression of displacement vs distance

2019

- Report after the Project Meeting – location to be discussed
- Final Report after the Project Meeting during the INQUA Meeting in Dublin;
- Consolidation of calculations and edition of 1) updated relationships M=fault parameters and of 2) attenuation regression between surface displacement and distance, given M

The results of the actions in Task 1 will concern these case studies using identified techniques and will consist of methodological notes. All this can be diffused and discussed by the scientific community during the next INQUA meetings or sessions organized by the Focus Group.

The concrete outcome from the actions in Task 2 will be an updated scaling relationship between magnitude and surface rupture parameters. We will provide complementary geological info on the factors locally controlling fault ruptures, which will help to a better understanding on the variability depicted by empirical laws.

The concrete outcome of Task 3 is a georefenced database of historical and recent earthquake surface rupture with detailed information on fault segment map, displacement measurement, type of soil.

10. Anticipated publications. (Project leaders are encouraged to publish project results in *Quaternary International.)*

- 2016 : Outcomes of the Kick-off meeting in Paris (Working Group “Surface rupture database”) will be proposed to publication in Proceedings of Crestone PATA Days;
- 2016 : Special Issue of Quaternary International Journal focused on the Fucino 2015 International Workshop
- 2017 : Proceedings of NZ conference;
- 2018 : “State-of-Progress” of the Working Group “Surface rupture database”
- 2019 : Proceedings Dublin INQUA Meeting + Publication of updated scaling laws and upgraded attenuation relationships

11. Other initiatives addressing this area of science. Please provide details of any such activities and explain how the proposed project differs from or will enhance ongoing initiatives. Please indicate whether you have been in contact with these groups to discuss future synergies/interactions.

A long-lasting collaboration exists between the Focus Group members and the IAEA ISSC.

Signature: __ _____________ Date: _______30/11)2015____

PROPOSED BUDGET

Please complete the table below, giving the full costs (in Euros) in the third column and the amount requested from INQUA for any allowable item in the fourth column. If the item involves funding e.g. travel or subsistence for a specific person, they should be named in the second column.

Item	**Person involved (and status)**	**Cost (in Euros)**	**Funding requested from INQUA**
Registration Fee Grants for the 2016 Project Workshop	PhD Students and ECR from different countries (10 p x 180€ = 1800 €)	1800 €	1800 €
Grants for partial travel support 2016 Project Workshop	PhD Students/ECR people and SS from Developing countries and/or Medium to low incoming countries (10p x 400€ = 5000 €)	Depending on the provenance countries the estimated cost: 12.000 - 10.000 €	4000 €
Accommodation Grants 2016 Project Workshop	PhD Students/ECR people and SS from Developing countries and/or Medium to low incoming countries (5p x 200€ = 1000 €)	Accommodation during the workshop will be at low-rates about (50 €/night x 4 nights) = 200 €	1000 €
Totals		**15.800* €**	**6.800 €**

BUDGET JUSTIFICATION

Item	**Justification**	**Link to outcomes/products**
Registration Fee Grants for the 2016	Facilitate the attendance of PhD Students/ECR people to the 2016 Workshop meeting. Oral/poster presentation required.	Involve young scientists to the project and facilitate the publication of their research material from different parts of the world.
Grants for partial travel support 2016 Project Workshop	Partial support to travel costs to attend the 2016 Workshop meeting. Oral/poster presentation required.	Same
Accommodation Grants 2016 Project Workshop	Full support to accommodation costs during the 2016 Workshop meeting. Oral/poster presentation required.	Same

ADDITIONAL SUPPORT FROM OTHER ORGANIZATIONS

We recognize that INQUA may not be able to provide all the level of support that you need for an activity. Please specify additional sources of funding (in Euros) for this activity in the table below.

Source	**Amount requested**	**Status** Confirmed (C), pending confirmation (P), application to be made (TA)
IRSN Sponsor of a business meeting (Paris) on surface rupture database and edition of proceedings	15,000	C (ref. O. Scotti)
IRSN Temporary position to implement the dataset	100,000 €	P (ref. O. Scotti)
IAEA-ISSC (Vienna) support for the implementation of Surface Rupture database and participation in 2016 Workshop	7,000 €	TA (ref. Yoshi Fuskushima)
IRSN support for participation to 2016 workshop travelling	2,000	C (ref. S. Baize)
University Aachen support for participation to 2016 workshop travelling	2,000	P (ref. K. Reicherter)

Please note: INQUA grants may be held in institutional or non-institutional accounts. Because INQUA requires that its limited funding is specifically used to assist Developing Country and Early Career scientists, it does not allow overheads to be taken off its grants. In the case of institutional accounts, INQUA anticipates that the institution will waive any overheads normally charged. In case of non-institutional accounts, it is the Project Leader's responsibility to make sure that his/her institution allows this, and that all formalities and legalities are observed. Grants are normally transferred to the Project Leader. However, at the Project Leader's request they can be transferred to a co-leader or local organizer.

Signature: _________________ **Date: __30/11/2015 ___**