Acronyme	**SISCOR**		
Titre du projet en français	Aléas, dynamique **sis**mogène, et couplages sismiques/asismiques d'un systeme de faille actives dans la région ouest du Rift de **Cor**inthe, Grèce		
Titre du projet en anglais	Hazard, seismogenic dynamics, and seismic/aseismic coupling of an active fault system in the western Rift of Corinth, Greece.		
Comité d'Evaluation référence (CE)[1]	SIMI 6		
Projet multidisciplinaire	☐ OUI ✠ NON Si oui, indiquer l'intitulé du second CE		
Coopération internationale (si applicable)	Le projet propose une coopération internationale ☐ avec les Etats-Unis (accord ANR/NSF) ✠ autres pays :		
Aide totale demandée	752185 keuros	**Durée du projet**	36 mois

SOMMAIRE

[1] Indiquer la référence du CE choisi pour l'évaluation du projet (cf. tableaux page 3 et 4 du texte de l'appel à projets)

1. Contexte et positionnement du projet / context and positionning of the proposal

1.1 Contexte:

In the last two decades, considerable observational and theoretical work has been devoted to all aspects of earthquake prediction research, for solving fundamental questions concerning the mechanics of fault systems, as well as for answering more applied questions related to hazard and risk. In the present project, we take the general meaning of the word “prediction”, as a quantification of the probability of earthquake occurrence in a given range of magnitude, space, and time. This problem spans several different time scales, usually classified into « long term » (time-independent, with quantification of long term fault activity), « medium term » (time scale of decades, with identification of specific faults stressed near their failure point), and « short term » (time scales of minutes to years, with the identification of so-called “precursors” on faults or fault systems).

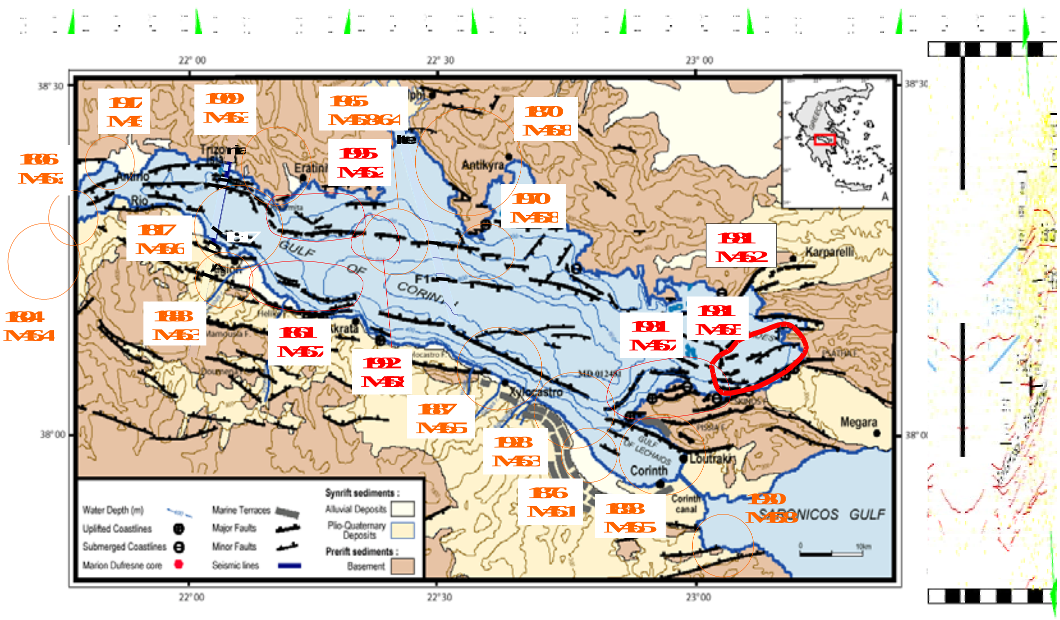
The latter, short term prediction approach has been the subject for intense controversy for half a century, as precursors were mostly identified as such after large earthquakes (post-prediction), and because no uncertainty range nor probability was associated to the “predictions”. A debate in the journal Nature (http://www.nature.com/nature/debates/earthquake/, 1999) provides an interesting overview on the subject, linked to the question of earthquake predictability owing to the possibly chaotic nature or self-organized criticality (SOC) of earthquake activity (see also the special issue of *Tectonophysics* on Earthquake Prediction , *vol 33, Issues 3-4, 2001*).

Whatever the time scale, these approaches for prediction all rely on some probabilistic description of earthquake generation and timing, through empirical laws guided, or structured, by some simplification of the underlying physical process.

Improving our ability to predict earthquakes thus requires that the relevant physical models and observational constraints are put at the core of these probabilistic laws.

Earthquakes generation is determined by the combination of secular strain (tectonic loading) with medium/short term cross-triggering between seismic events (large or small), or even between earthquakes and slower transient strain processes in the crust (fault creep, migration of pore pressure pulses, seismic swarm activity,...). For seismic coupling, the cross-triggering effect is presently described by extremely simplified laws integrating distance effect (power laws), time dependence (Omori law), magnitude distribution of the triggered events (Gutenberg-Richter law), and triggering intensity (e.g., Helmstetter et al., 2006). Quantification of earthquake triggering by slow transient is just recently being considered (ANR jeune chercheur 2008, project ASEISMIC), as transients are generally poorly, if at all detected. In addition to triggering capabilities, these transients may play a considerable role in earthquake preparation, loading potentially seismic asperities, or stabilizing others, as well as in significantly contributing to the long term strain budget. Their tracking and modelling will form the bulk of international research effort of the coming decades. In this context, « precursors » to earthquakes are simply a small subclass of transients which happened to trigger or herald a large seismic instability (e.g., Bernard, 2001). Whether specific characteristics distinguish this subclass from self-dying, ordinary transients remains an open question.

Thus, from the mechanical point of view, for a given fault system, the long term, medium term, and short term (i.e., transients) observational constraints are all necessary for building a comprehensive physical model integrating all spatial and time scales, and for allowing some reliable prediction of their evolution. This is mainly because all spatial scales strongly interact, with upscale and downscale transfer of energy on a hierarchical system of coupled faults. Thus, the identification of large paleo-earthquakes, the quantification of the probability of future single dynamic ruptures involving several fault segments, the understanding of the mechanical rupture of small asperities, or the determination of the slip/aseismic coupling on the deepest surface of faults, are all important for assessing future hazard, being coupled components of the global space-time mechanical processes. All these components require improved observational and modeling tools and methodologies.



1.2 Positionnement

Figure 1: seismotectonic context of the rift of Corinth, with faults and seismicity.

Top: *1800-to present large earthquakes for magnitudes> 5.5-6.0 ; ellipses are for rupture area (red for instrumental, orange for historical seismicity)*

Bottom: *Green dots: seismicity 1964-june 2008, from National Observatory of Athens (M>3, depth 0-20 km). Blue rectangle: Aigion 1995 earthquake area. Red: major active faults (offshore faults from Moretti et al., 2003; onland faults from Pantosti et al., 2007; Rigo, 1994; Kiratzi et al., 2008). Green arrow: extension of the Corinth rift , 1.5 cm/yr (from Rigo et al., 1996).*

In this context, our project aims at providing new key observational elements, in a specific region, as well as improved methodologies, for contributing to testing and refining the prediction laws and the underlying physical models of earthquake generation and fault activity, including transients. The selected seismic region is an active normal fault system in the western part of the Rift of Corinth, in Greece, covering an area 40 km x 40 km. It consists of a system of parallel, en-echelon normal faults, with segments 5 to 20 km long, mostly dipping to the north, with some antithetic normal faults.

Some 20 years of research have been done in the framework of several national (France - INSU, ANR- and Greece) and EU projects (7 in total, all coordinated by France), for the development of which several partners of the present project have played a key role. After 10 years of preliminary temporary experiments and field work in the broader rift, this restricted area near the city of Aigion was defined in 2000 as the target for the Corinth Rift Laboratory

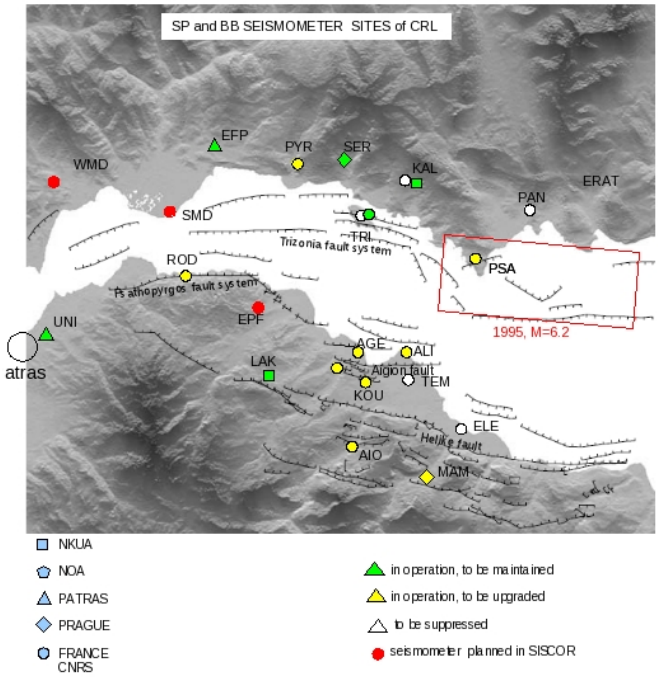
(CRL) which is an international pilot site for continuous monitoring and multidisciplinary research on earthquake processes (see Cornet et al., 2004, and http://crlab.eu).

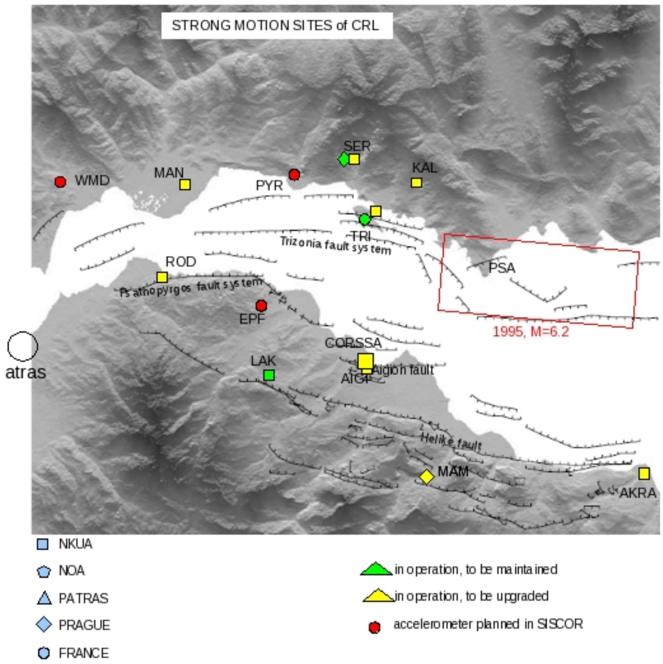
The motivation for launching the CRL was manifold:

- the Corinth rift is the most active continental seismic region of the Mediterranean basin, with 10 destructive earthquakes per century (Magnitude >6), among which 4 in the selected region of CRL. It is one of the fastest opening continental rifts in the world, with an opening rate of 1.5 cm/year in the CRL target area.
- the eastern part of the CRL research area was the site of the last destructive earthquake, in 1995, (M=6.2) and of the large 1861 event (M=6.7).
- the central part of the CRL area has not ruptured since the last destructive earthquake of 1887, and the western part of this area has no reported large earthquakes, since at least 300 years: the faults there are thus the target of a medium term prediction of one or two destructive earthquakes within a couple of decades (Bernard et al., 2006), but this is still not properly quantified.

Within the CRL, since 2001, continuous monitoring for seismology, and more recently for GPS and strain provides an exceptional data base which is presently analysed by several teams (http://bdsis.u-strasbg.fr/BDsis for seismological data, https://gpscope.dt.insu.cnrs.fr/chantiers/corinthe for GPS continuous data). These monitoring arrays of CRL presented in Fig. 2, were recognized as « Site instrumenté » by CNRS/INSU in 2009, for long term measurements (see attached document in Annex). A Scientific Board and Steering Committee for CRL will be proposed to INSU in January 2010.

One important specificity of the CRL with respect to the other densely instrumented fault sites in the world is that it is the first one developed within an extensional tectonic regime. Another pilot site within a similar tectonic context has been more recently developed in the Appenines, near Naples, but the strain rate and microseismicity level is at least 5 times lower than Corinth (e.g. http://www.rissclab.unina.it/content/view/622/304/lang,it/, Serpeloni et al., 2005). The other sites, all outside Europe, are dominated by strike-slip deformation as for the Parkfield, California site (see http://earthquake.usgs.gov/research/parkfield/, and http://www.earthscope.org/observatories/safod) or thrust tectonics as in Japan (see http://www.j-shis.bosai.go.jp/j-shis/index_en.html) in the Tokai region near Tokyo (e.g., Ito et al., 2007), and may thus present different transient and seismic coupling processes.


SP and BB SEISMOMETER SITES of CRL
WMD
EFP
PYR
SER
KAL
PAN
ERAT
SMD
TRI
Trizonia fault system
ROD
Psathopyrgos fault system
PSA
1995, M=6.2
EPF
UNI
atras
LAK
AGE
ALI
Aigion fault
TEM
KOU
ELE
Helike fault
AIO
MAM
NKUA
NOA
PATRAS
PRAGUE
FRANCE CNRS
in operation, to be maintained
in operation, to be upgraded
to be suppressed
seismometer planned in SISCOR


STRONG MOTION SITES of CRL
WMD
MAN
PYR
SER
KAL
TRI
Trizonia fault system
ROD
Psathopyrgos fault system
PSA
1995, M=6.2
EPF
atras
LAK
CORSSA
AIGF
Aigion fault
Helike fault
MAM
AKRA
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NOA
PATRAS
PRAGUE
FRANCE
in operation, to be maintained
in operation, to be upgraded
accelerometer planned in SISCOR

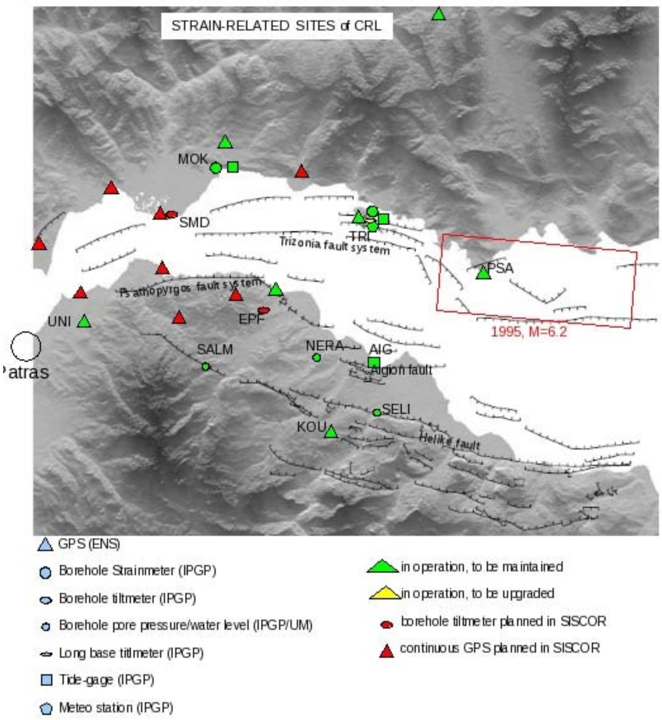

STRAIN-RELATED SITES of CRL
MOK
SMD
TRI
Trizonia fault system
PSA
1995, M=6.2
Psathopyrgos fault system
EPF
UNI
Patras
SALM
NERA
AIG
Aigion fault
SELI
KOU
Helike fault
GPS (ENS)
Borehole Strainmeter (IPGP)
Borehole tiltmeter (IPGP)
Borehole pore pressure/water level (IPGP/UM)
Long base tiltmeter (IPGP)
Tide-gage (IPGP)
Meteo station (IPGP)
in operation, to be maintained
in operation, to be upgraded
borehole tiltmeter planned in SISCOR
continuous GPS planned in SISCOR

Fig. 2: Monitoring arrays of CRL
***top left:** short period and broadband seismometers ; **top right:** accelerometers ; bottom: GPS, strainmeters, tiltmeters. Tide-gages. **For all:** In red are the instruments planned in SISCOR. Note that 1km deep, instrumented AIG10 borehole crossing the Aigion fault (Cornet et al. 2004) is not in operation anymore.*

In recent years, analysis of the CRL data has led to important, new results, concerning the structure and activity of the fault system (e.g., Bernard et al. 2006). Major surface faults (onshore and offshore) appear to branch at around 5-6 km depth into a shallowly dipping zone of high microseismicity, a couple of kilometers thick, defined by temporary swarms of earthquakes concentrated on smaller faults or fractures. This swarm activity results in very large fluctuation of the seismicity level (from 10 events per day in quiet periods to several hundreds per day during swarms, over several weeks). This seismic layer seems to be presently steadily creeping at high rate (Avallone et al., 2004). It corresponds to a highly fractured lithology as deduced from tomographic images (Latorre et al. ,2004; Gautier et al., 2006), with high pore pressures as inferred from seismicity mechanisms and migration (Bourouis and Cornet, 2009).

The evolution of the fault system, and the present-day geometries of and distribution of activity on the offshore faults remain a topic of research within the CRL and others groups (Palyvos et al. 2005, 2008, Moretti 2003, McNeill et al. 2004, 2005; Bell et al. 2008, 2009). Debated issues include the degree and significance of asymmetry in the fault system (McNeill et al. 2005; Jolivet et al. 2009), the northward migration of fault activity (Goldsworthy and Jackson 2001; Ford et al. 2007), the distribution of deformation on the fault system and how this evolves in space and time (Rohais et al 2007; Leeder and Mack 2007; Leeder et al. 2008; Ford et al. in prep).

More detailed presentations on the recent developments of the CRL research can be found in
http://www.crpg.cnrs-nancy.fr/NEWS/Corinthe3F/corintheprog.html

Many questions remain open for the CRL, concerning the most recent evolution of the fault system, the history of past large earthquakes, the mechanical processes presently at work in the centre of the rift (creep, pore pressure transients, earthquake swarms), and the resulting probability of future destructive earthquakes. Addressing these questions require new data, and the implementation of adequate methodologies and modeling tools. These objectives motivate the present project, by using an integrated, multiscale approach. The latter may be facilitated by the mostly stationary extension to the south and to the north of the target area, by the small strain rates to the west, and by the recently relaxed fault to the east, which altogether provide simple boundary conditions for the unstable mechanical system lying near the centre of the area.

Last but not least, a reliable and accurate earthquake hazard assessment appears particularly relevant for socio-economic reasons. Indeed, the city of Aigion (pop. 35,000) is crossed by one of the threatening faults, and the city of Patras (pop. 300,000), as well as a large infrastructure, the 3 km long Rio-Antirio bridge, stand at a few kilometers from the tip of another threatening fault. Assessment of regional seismic ground motion hazard, not considered in the present project, will be an immediate follow up. Finally, the generic aspects of the models and methodologies developed in the project will hopefully contribute to the study of earthquake hazard and geophysical processes in other seismically active areas of the world.

2. DESCRIPTION SCIENTIFIQUE ET TECHNIQUE / SCIENTIFIC AND TECHNICAL DESCRIPTION

2.1. ÉTAT DE L'ART / BACKGROUND, STATE OF THE ART

2.1.1 Geometry and recent history of the major fault system

The Corinth fault system records the early stages of rift evolution on a relatively short geological time scale (<5 Ma) (e.g., Armijo et al., 1996). It is illustrated in Fig. 1. The CRL research area lies at the W end of the rift. Just to the west of the Psathopyrgos fault a NNE-SSW transfer fault zone links the Corinth rift with the Patras rift to the SW (Rion-Patras transfer fault of Flotté et al. 2005). The normal fault system, syn-rift stratigraphy and geomorphology of various parts of the onshore CRL area have been described and analysed (Flotté 2003 Flotté et al. 2005; Palyvos et al. 2005; 2008; Ford et al. 2007; Backert et al. 2009; Rohais et al. 2007). Major active faults are concentrated along the coast or below the Gulf. Older faults are uplifted and inactive to the south. While the East and West Helike faults are thought to have initiated around 800 ka (Ford et al. 2007), The Psathopyrgos Fault is estimated to have initiated some time between 300 and 400 ka (Palyvos et al. 2009) when activity on the main fault to the south (Lakka fault) ceased. In the area between the West Helike fault and the Psathopyrgos fault, complex vertical motions interact with young fault activity and a marked northward migration of fault activity.

Over 2 km of vertical displacement may have been accommodated on the Psathopyrgos Fault. Footwall uplift has been recently estimated as 1.71-1.85 mm/yr (Palyvos et al. 2009). The area is also characterised by a high supply of coarse sediment by antecedent rivers, that are deposited as thick deltas in the immediate hangingwalls of major faults.

From the studies above, the major, presently active normal faults are concentrated along the southern shores of the western gulf. For clarity, we present in the sketch below (fig. 3) only the most significant ones, quoted in the project, dismissing in particular the more ancient, mostly inactive faults to the south, and recent, second order offshore faults.

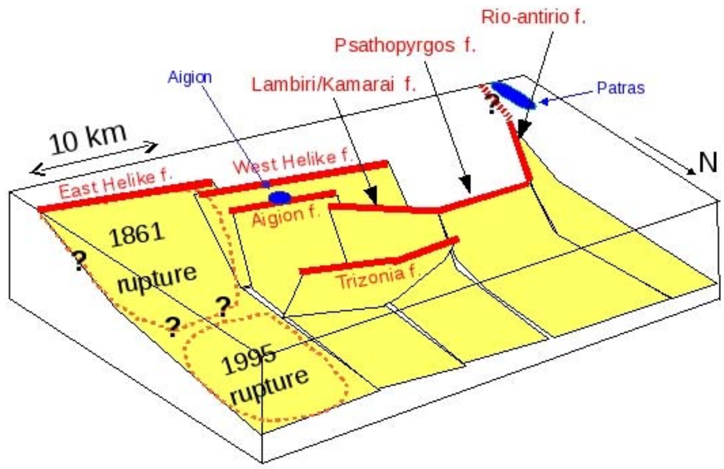


Figure 3: sketch of the major active faults of the CRL area. Surface scarps in red. Trizonia fault is the only south dipping fault. The 1995 may have occurred on the Helike fault (uncertain dip and connectivity)

On the southern shore, one finds the East Helike fault (rupture in 1861, and possibly 1995 in its deeper part), the West Helike fault, less active; to its north, the smaller Aigion fault, connected to the Psathopyrgos fault through the Kamarai and Lambiri relay faults. To the north, the dominant fault is the south-dipping, offshore Trizonia fault. The growth of the Psathopyrgos fault (starting 400 kyr BP) may be related to the locking of the west Helike fault, and possibly guided the more recent formation and propagation of the Aigion/Kamarai/Lambiri faults (50 kyr ?). The history and activity of the south dipping Trizonia fault remains largely unknown as do the other antithetic faults below the gulf identified by Bell et al. (2008, 2009).

2.1.2 identification of past large and moderate earthquakes at CRL

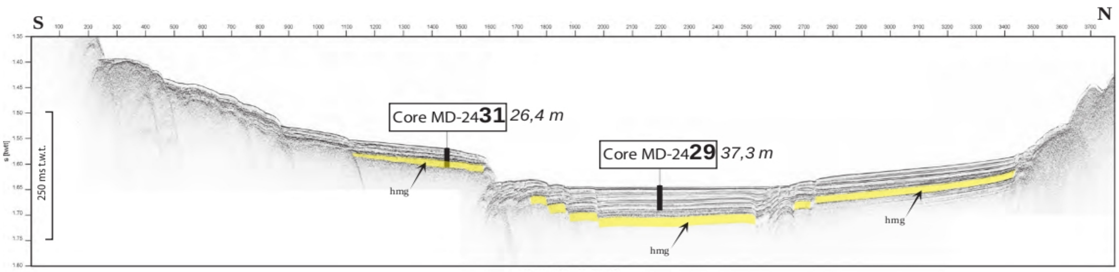
- The region is well instrumented since 1964 at the regional scale (NOA), and since 10 years at the CRL scale. Historical seismicity records for this region have been searched for, and have been already exploited for the most recent events (Ambraseys and Jackson, 1990; see also http://emidius.mi.ingv.it/neries_NA4/). The table below, extracted from Papazachos and Papazachos (1987, 2003), presents most of the known historical earthquakes. The historical catalogue of large earthquakes in the rift of Corinth is probably complete above magnitude 6 for the last 3 centuries, but these events remain however poorly constrained for the period pre-dating 1890. In the CRL area, the only earthquakes with unambiguous identification of the causative fault are the 1995 and 1861 events (Bernard et al., 1997; Schmitt, 1881).

year	373BC	23	1580	1714	1748	1785	1804	1806	1817	1861	1888	1909	1917	1965
city	helike	Aigio	Phokida	Patras	Aigion	Patras	Patras	Patras	Aigio	Valimitika	Aigio	Phokida	Nafpactos	Eratini
I		VIII	X	IX	IX	IX	IX	VIII	X	X	IX	VIII	VIII	VIII
M	7	6.5	6.7	6.6	6.8	6.6	6.6	6.3	6.5	6.7	6.2	6.2	6.0	6.3

- Long term slip rate on fault as well as recent GPS data (Avallone et al. 2004) suggest a recurrence time of a couple of centuries for the fastest faults. Recent paleoseismological data with trenching or paleo-shoreline studies (Lemeille et al. 2004; Pantosti et al. 2004) identified a few large events in the last 5000 years, but many large events of this period have probably been missed.

- Archeological investigations have been developed in the area of the Helike fault (cf. Helike Society, http://www.helikeproject.gr/publications.htm; Alvarez-Zarikian, 2008; Katsonopoulou et al., 2003) revealing previously unknown earthquakes in Roman times, but other identified sites remain to be studied.

- A longer paleoseismological record can be obtained using the marine sedimentary archive of the Gulf and particularly mass wasting events triggered by earthquakes can be used. Paleoseismic methodologies for the lacustrine and submarine environments (Goldfinger et al., 2003; Nakajima et al., 2000; Fujiwara et al., 2000; Gorsline et al., 2000) are not as well established as for land, but it is a rapidly developing new field of study with considerable potential. French teams in this discipline are currently focussing their efforts in Marmara, Venezuela, and Corinth (Beck et al, 2007; Carrillo et al., 2008; Van Welden, 2007). In Japan, IODP supports a major project in Tokyo bay. In the USA and Israel, paleoseismological research projects are studying lacustrine sediments (Kent et al., 2005; Begin et al., 2005) and turbidites offshore California and Oregon (Goldfinger et al., 2003). This technique has proved successful in the central and eastern part of the Corinth rift, with long cores retrieved by the Marion Dufresne (Moretti et al. 2004) (see Fig. 4) and sedimentary disturbances associated with the 1995 Aigio Earthquake identified (Van Welden 2007). The steep (up to 28°) offshore slopes of fan deltas in the western Gulf of Corinth makes this technique very promising for CRL, using calibration with known historical earthquakes.



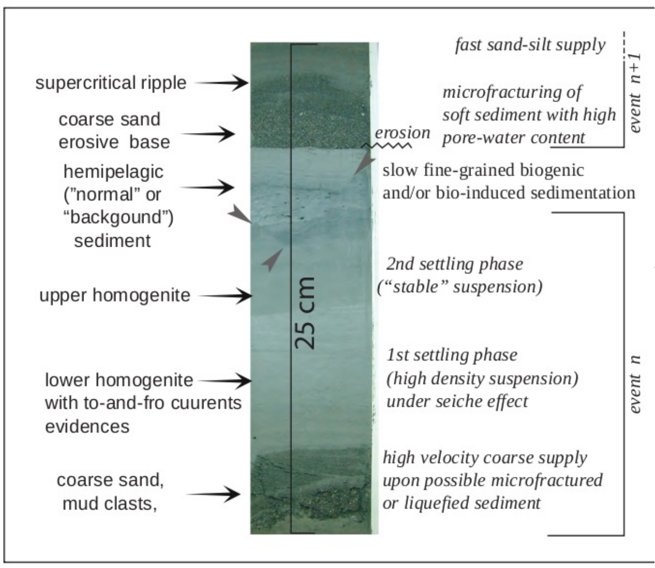


Figure 4: identification of turbidites in shallow sediments. Top : 3.5 kHz profile across the Sea of Marmara's Central Basin, displaying a deep-seated thick homogenite dated back to 16000 yr BP (MARMARASCARPS Cruise). ***Bottom:*** *Split core view of a sedimentary event*

(turbidite/homogenite) attributed to a co-seismic triggering. (MARMACORE Cruise Sea of Marmara's Central Basin)

- A puzzling observation in the history of local earthquakes is that the Psathopyrgos normal fault, which defines the western end of the rift, is not associated with any significant earthquake (the 1917 event may only have reached the moderate magnitude 5.5). This is compatible with a mean interseismic strain rate equal to the rate determined in the 2 last decade by GPS (>1 cm/yr) only if a coseismic slip of more than 3 m occurs (Magnitude>6.5-7) in the next decades. Alternatively, the present strain rate from GPS could be larger than the mean interseismic rate (present acceleration of strain). This strain acceleration phase could then be premonitory to a major earthquake (M>6), but alternatively may die out on a time scale of years to decades with no major event. Thus, determining the occurrence or not of large earthquake(s) in the past few thousands of years for this fault has major consequences for our understanding of its mechanical behaviour (intermittent creep with no stress building, or stick-slip with large earthquakes), and on the associated hazard of the CRL area (Bernard et al. 2008).

In conclusion, there is a clear lack of essential data for past large earthquakes in the area, to be gathered by high resolution studies using historical, archeological, and geological/sedimentological archives.

2.1.3 Fault geometries and crustal structures at depth from the CRL seismic data base

A global relocation of 8 years of microseismicity data (mostly swarms) by double difference techniques and multiplet analysis has started to reveal the detailed fault structure at depth on the eastern CRL area (East Helike fault, and offshore 1995 rupture segment) and on the central area (Western Helike, Aigion fault, and antithetic Trizonia fault) (Lambotte et al., 2008) (fig. 5). A refined study of the 2001 swarm, south of the rift, demonstrates the activation of a hidden, previously unknown oblique fault which may to be related to a yet poorly defined NS structural boundary crossing the rift (Pacchiani and Lyon-Caen, 2010).

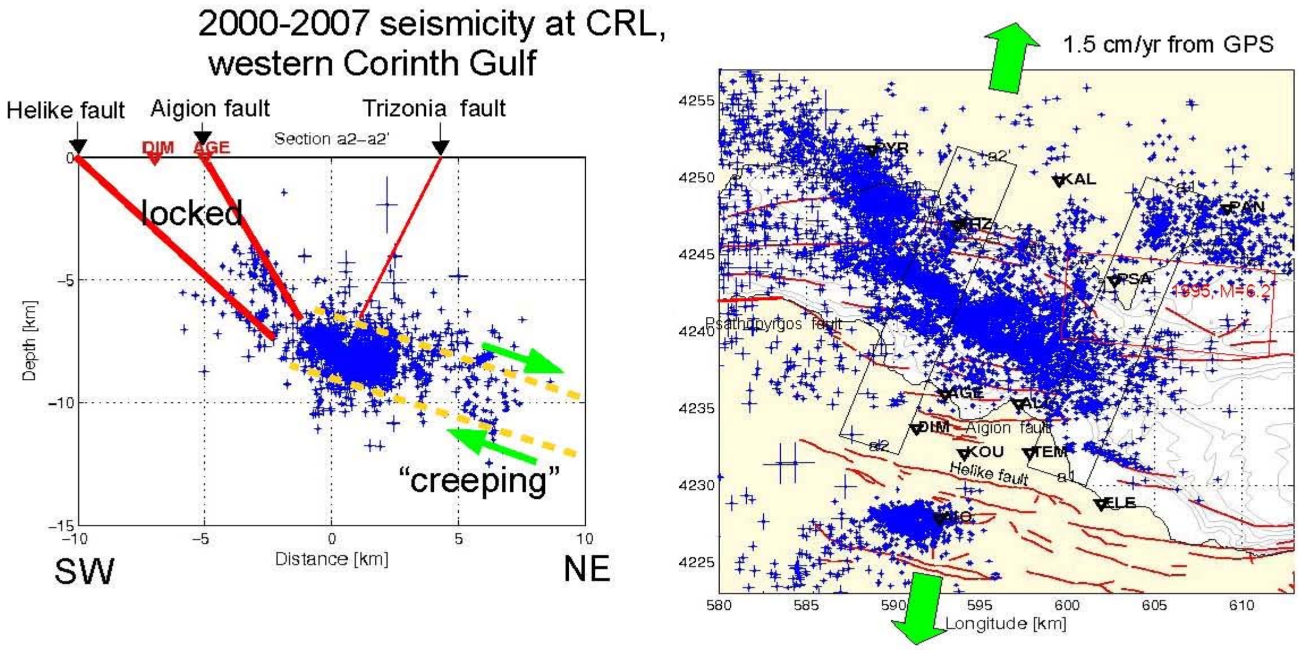


Fig. 5: 8 years of microseismicity from the CRL array.

Left: *SW-NE vertical cross section/ Microseismicity hypocenters in blue. Presently mostly locked faults in red. Creep deduced from GPS in green.* ***Right:*** *faults in red; epicenters in blue; GPS rate in green. The low level of microseismicity near the Psathopyrgos fault (western end of the Gulf) is a bias due to its location outside the CRL seismic array (see fig 1. bottom, for comparison, in the absence of bias for the NOA regional array).*

2.1.4 detection/analysis of steady and transient creep from the CRL data base

- A GPS network of 60 first order points and around 200 second order points has been created in the early 1990's in the whole Gulf of Corinth. The first order points have been reoccupied regularly allowing to assessing the extension rate across the Gulf (Avallone et al., 2004). Additional points have been measured twice, within the 3HAZ project (2004-2006), directly on the Psathopyrgos foot wall.
- The relocated microseismicity shows a slow migration and/or spreading of the largest seismic swarms, which suggests the propagation of creep perturbation, or/and of pore pressure in the highly fractured fault systems of the rift axis (Bourouis and Cornet, 2009). The detailed space-time analysis of seismicity remains to be done. No tectonic tremors have

yet been detected, but a systematic search over the whole CRL data base remains to be done.

- Bursts of micro-seismic activity occurs on previously undetected faults, to the south like in 2001, or to the north on south-dipping, blind faults.
- The western CRL area, controlled by the Psathopyrgos fault, lies outside the CRL monitoring seismic array (see Fig. 2) (the closest station, ROD, is operated only since 2009): the seismicity remains poorly defined, so that the structure, segmentation, and activity of this fault remains largely unknown. Large seismic swarms, of several weeks duration, occurred in 2002 and 2009 on this fault, which was activated at depth over most of its length (15 km); the largest event of the 2002 swarm coincided with the peak of a compression transient, lasting 30 minutes, recorded on a borehole strainmeter, and was interpreted as a slow slip event (slow earthquake) of equivalent magnitude 5 (10 cm of slip) (Bernard et al., 2006, 2008). These swarms are interpreted as large-scale creep activation of the fault surface (see also Parcharides et al., 2009) , which could arise more or less regularly. To our knowledge, there is no report for episodically creeping normal faults in a non-magmatic environment. Closer and denser seismic and strain arrays are needed for a better understanding of this intermittent process.
- The continuous GPS (cGPS) array of CRL, 6 stations, together with the repeated GPS surveys, only provide a rough image of the interseismic strain (typical resolution 5.10^{-7}), and locked asperities smaller than 10 km are not resolved yet. On the cGPS, the long term displacement of stations is modulated by a seasonal signal. No clear transient or strain rate change appears for the last 5 years of operation. Borehole dilatometer and strainmeter continuous records, with a resolution of 10^{-10}, are presently analyzed for detecting strain transients, in particular those possibly related with seismic swarms. No transient has been recorded in the recent years above the tidal signal, except for the 2002 transient (see above).
- The refined analysis of multiplets shows that the 2001 swarm was associated to a change in the seismic velocities of the crust in the vicinity of the closest stations, which is not yet explained (Cociani et al., in revision, 2010).

2.1.5 mechanical modeling at various time scales:

2.1.5.a Kinematic modelling (defined by slip or slip rate distributions)

- 10 ky – 500 ky – The jump in fault activity from the West Helike fault to the Psathopyrgos fault is estimated by Palyvos (2009) to have started between 300ka and 400 Kyr BP. The chronology of the activation of the other faults (Aigion, Lambiri, Kamarai, Trizonia,…)

remains to be established. Preliminary correlations of recently established syn-rift stratigraphy and fault histories (Palyvos et al. 2009; Ford et al. 2007; Backert et al. 2009) suggest that fault activity migrated not only northward but also westward to open the Rion straits in the Middle to Late Pleistocene.

- 1 Kyr – present . Average slip rates were recently estimated for the major faults (McNeill et al., 2005; De Martini et al., 2004).

- decade: One decade of GPS repeated survey has been modelled with a simple elastic, 2D model, demonstrating the major creeping activity of the central seismically layer (Avallone et al., 2004)

- hour: The 2002 slow earthquake was modelled with a simple kinematic model in a 3D elastic, layered crust (Bernard et al., 2008)

- second: The 1995 Aigion earthquake was modelled with a uniform slip in a 3D elastic space to fit seismic and GPS data (Bernard et al., 1997)

2.1.5.b Mechanical modelling (defined by constitutive or physical laws) :

Applied to CRL:

- 10 ky – 500 kyr: A simplified 2D visco-elastic numerical model of the evolution of the western Corinth rift, integrating erosion and sedimentation has been developed, showing in particular the northward progression of normal faults and fan deltas (Rohais , 2007)

- 1 kyr- 50 kyr: A simplified 2D visco-elastic model of the rift has shown the need for early activation of the Trizonia fault to fit the long term morphotectonics (Cianetti et al., 2008).

Developped and applied outside CRL

- 3D mechanical modeling of a non-elastic crust with faults (cohesive zones) has been recently implemented with the Z-set/Zebulon F.E. mechanics software, developed by Ecole des Mines de Paris, ONERA, and Northwest Numerics (cf. http://zebulon.onera.fr/French/index.html). with an application in progress to the 2004 Sumatra earthquake postseismic relaxation (Garaud et al., 2009).

- years to decades – the triggering capabilities of large earthquake was first quantitatively considered for the medium term prediction of the future Marmara sea earthquake on the northern Anatolian fault (Parsons et al., 2000). Routine analysis of real-time seismicity produces updated probability estimates of seismic activity based on earthquake triggering laws for which statistical tests are under development. (e.g., Working Group on California Earthquake Probabilities SCEC, http://www.scec.org/research/projects/WGCEP/)

- 1s - 1 minute: The effect of fault segmentation on seismic rupture (slow down, delay, or stopping of the rupture front) is now integrated in 3D numerical simulation of elastodynamic rupture propagation (Oglesby et al., 2003; Oglesby et al., 2008), allowing estimates of probabilities for large magnitudes for given geometries of fault systems (e.g., Aochi, 2005, for a prediction in Durance valley).

- 10 years-1 s: rate-and-state friction 3D models have been used for modelling sequences of large rupture on fault planes steadily loaded (e.g., Kato, 2002) , but have not yet been used for modelling small-scale asperity rupture and interaction forced by creep.

There is thus a clear lack of 3D, long term kinematic description of the faults at CRL, as well as of 3D mechanical modelling of the rifting process with numerical models involving realistic rheologies or constitutive laws. Mechanical models of dynamic rupture and of short term fault interaction and cross-triggering are also missing.

2.1.6 probabilistic estimates of fault activity: integration of previous data and models for prediction

- From the methodological point of view, on a world-wide basis, the identification and quantitative description of major loaded (seismic asperities) and unloaded (aseismically creeping) patches on fault surfaces are often dismissed in the estimate of the seismic activity of a given fault due to the lack of data. This is however a critical issue for defining a correct magnitude range of future earthquakes, for integrating historical and instrumental seismicity, and finally for accurately assessing the seismic hazard. Furthermore, possible time dependence of the loading and creep rate in the interseismic period (short term GPS versus long term tectonics) should be considered, to correctly handle the strain budget.

- The slow but continuous increase of knowledge on the seismic potential of some well studied fault systems, in areas of high but also of moderate seismicity, leads to the problem of defining, within a probabilistic approach, the plausible activity of some faults. Indeed, the seismicity must be split into the fault-related events on one side, and the activity of the surrounding unknown faults on the other, which is not an obvious task. This technique is applied in most seismic hazard studies; it is in continuous development, with the USGS in the leading position as far innovative modelling approaches are concerned (see SCEC/USGS websites, Cybershake 2007). In Europe, there is a similar probabilistic approach for the Marmara region (Erdik et al., 2004; Atakan et al., 2002) .

- In the CRL area, the major active faults with potential M>6 earthquakes are now identified, from tectonic (e.g., McNeill et al. 2005) and seismological studies (Bernard et al., 2006), but their geometry at depth and activity is poorly constrained. Previously unreported, hidden faults are also activated, with moderate events (M=4 to 5), such as some antithetic faults growing on the northern side of the rift, as a recent response to the northward shift of the fault activity, or old ones as in 2001, but their potential for larger events is unknown (Pacchiani and Lyon-Caen, 2010).

- Finally, the suggestion that "the probability of at least one moderate to large earthquakes (M=6.0 to 6.5) is thus very high within the next few decades " (Bernard et al., 2006), based on a crude analysis of historical seismicity and present strain rate, still remains an unquantified and fuzzy medium term prediction, requiring further study.

2.2. Objectifs et caractère ambitieux / novateur du projet / Rationale highlighting the originality and novelty of the proposal

The project is focussed on fundamental research on seismogenesis, and on the related probabilistic quantification of the time dependent earthquake hazard, in a fault system near the western end of the rift of Corinth, Greece. This research, with dense monitoring arrays, large open data base, multidisciplinary analysis, and mechanical modelling, is one of the most advanced of this type in Europe.

2.2.1 Main objectives:

- to understand and model the mechanics of a fault system, at various space and time scales, integrating secular tectonic loading, earthquake rupture and cross-triggering, transient (creep or seismic swarm) triggering, and seismic/aseismic coupling.
- to predict the time-dependent probabilities of large earthquakes in the area, with the quantification of potential fault activity and interaction.

2.2.1a Evolution of the fault system and identification of past large earthquakes at CRL

The objective is to provide new data on past earthquakes from various archives.

- Morphotectonic and Sedimentological archives, 10 kyr-300 kyr:

Constraining fault early history (propagation, strain distribution, uplift) by mapping geometry of the fault system, defining the character of the syn-rift succession and dating fault surfaces, syn-rift stratigraphy and footwall paleo-shorelines using Cl isotopes, U-series isotopes and cosmogenic nucleides.

- Sedimentological archives, 1 kyr - 10 kyr:

Research and analysis of offshore turbidite deposits will focus on dating and spatially constraining major earthquakes. These offshore sedimentary archives will be correlated with footwall uplift history by mapping and dating uplifted paleoshorelines building on the work of the INGV group (Pantosti, Palyvos et al. 2005, 2007).

- Historical archives, 300 yrs:

searching for archives attesting to the occurrence of past earthquakes down to magnitude 5; attributing historical earthquakes to their causative faults whenever possible; getting new knowledge of lower magnitude earthquakes along faults for constraining possible models of seismicity of each fault (characteristics vs. Gutenberg-Richter).

- Archeological archive, 2 kyrs:

excavation and paleo-sea level dating at an ancient harbour dock on an uplifted shore line.

2.2.1b Detection and analysis of seismicity and transients from the CRL data base (2000-2009+)

- densifying the seismic arrays for resolving the seismicity, geometry, and fine structure of the Psathopyrgos fault
- densifying the cGPS array for resolving the steady and transient creeping patches of the Psathopyrgos fault
- densifying the high resolution strain array for detecting small scale transients related to creeping event on the Psathopyrgos and neighbouring faults
- refined space-time analysis of microseismicity, for resolving the mode of rupture (strong asperities surrounded by creeping areas, or weak cracks in more resistant fault surfaces), and understanding the intermittent character of the swarms (transient creep, transient pore pressure pulse), in particular through the analysis of multiplets.
- research and kinematic modelling of strain transients, when observed on the high resolution strain measurements.
- in the perspective of a future large earthquake, the local accelerometer array will be densified. In case of such an event, seismological, geodetic, and tectonic research will immediately be launched for data analysis and modeling.

2.2.1c mechanical modeling at various time scales:

The data analyses above will provide the observational constraint for mechanical modelling of the underlying processes.

- Rate and state friction laws will be used and calibrated for fitting the multiplet, microseismic activity within the frame of an interacting asperity model (1 m- 1 km; 1 s – 10 years)
- Slip weakening friction laws will be used in 3D elastodynamic models for the propagation of rupture over several neighbouring fault segments. (5 km – 30 km; 1 s – 1 minute)
- Generalized Omori law with spatial dependence for earthquake interaction will be calibrated on the XXth century catalogue of the rift and used to predict medium term cascade events (5-30km; 1 hour- 10 years)
- Non elastic rheologies will be considered in 3D quasi-static modelling of interseismic activity of the fault system, integrating major creeping and locked areas of the major faults.(Z-set/Zebulon software)

2.2.1d probabilistic estimates of fault activity

The data and models above will be integrated for defining the probabilities of rupture of the major faults, as well as their time-dependence, in particular considering possible cross-triggering effects. To handle the various observational or epistemic uncertainties, the quantification will be based on a logic tree approach, integrating intrinsically probabilistic estimates, as well as weighted expert assessment.

2.2.2 Ambitious and innovative character

The ambitious and innovative character of the project relies on the integration of new instruments, new data, new methodologies, and new models, coming from various fields of geosciences (geology, seismology, geodesy, geophysics, ...) which will improve our understanding of fault mechanics and our ability to quantify earthquake prediction. Below are the main innovative propositions.

2.2.2a Multiscale Kinematics and Mechanics of a normal fault system

- first dense, multiparameter survey (seismicity and strain) in a seismically active region of Europe associated with a medium term earthquake prediction
- first pilot site in Europe with an array of several high resolution strainmeter sensors (borehole tilt and strainmeters)

- development of joint, multidisciplinary analysis of seismic and strain data, for assessing the coupling between seismic and aseismic transients
- new constraints for large seismic asperities and creeping patches during interseismic activity in an euromediterranean fault system.
- possibility of an intermittently creeping normal fault (Psathopyrgos fault), which would the first observation of this type
- first 3D mechanical modelling of small scale seismicity, with interacting asperities
- first 3D modelling of large scale dynamic rupture across normal fault segmentation
- first 3D, non elastic modelling of the global fault system in the rift, with creeping and locked sections
- first detailed description of the strain changes at the western tip of the Corinth rift, and of its partition to the NW (Agrinion lake rift system) and the SW (Patras strike-slip system and Patras rift)
- a consistent kinematic model of the long term evolution of the fault system in the western rift of Corinth.

2.2.2b Refine earthquake hazard assessment in western rift of Corinth

- first complete catalogue of destructive earthquakes (M>6) for the last 5000 years in the western rift of Corinth, in particular thanks to turbidite/mass wasting mapping using very high resolution seismic lines and dating of associated sedimentary cores.
- original methodological test on the use of sedimentary disturbances for past earthquake identification
- first quantitative assessment of the time-dependent probability of a destructive earthquake in the area (also first in Europe), based on past earthquake activity combined with theoretical potentiality for large cascade events.
- new methodological developments for time dependent seismic assessment.
- towards a “Uniform Corinth Golf Earthquake Rupture Forecast”, UCGERF, along the lines of http://www.scec.org/ucerf/

3. PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DU PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROJECT MANAGEMENT

3.1. PROGRAMME SCIENTIFIQUE ET STRUCTURATION DU PROJET / SCIENTIFIC PROGRAMME, SPECIFIC AIMS OF THE PROPOSAL

The structuration of the project is described in Fig. 6 and in the following, detailed list of Tasks. It is structured with 4 main Research Tasks.

The first Task concerns the observations and analysis of processes in the CRL region at the short/medium term time scale (1 s – decades), relevant for CRL monitoring arrays. It requires in particular new instrumentation and surveys, for progressing on the understanding of the mechanical activity of the Psathopyrgos fault.

The Task 2 concerns the study of long term processes (decades – 500 Kyrs). It aims at building a catalogue of past large earthquakes, with various source of information, and at understanding the evolution of the fault system. This is in particular requested for evaluating the seismic potential of the Psathopyrgos fault.

The Task 3 will integate geometrical and kinematic results from Task 1 and 2 to produce a global 3D kinematic model of the fault system, and to allow for the development of various 3D mechanical modeling of fault and seismic activity. In particular, it will simulate the development of earthquake sequences over many seismic cycles, taking into account cross-triggering and stress transfer.

The Task 4 will integrate the results from the previous 3 Tasks in a logic tree approach for evaluating the likelihood of large earhquake in the coming decades. Methodological developments will be requested for integrating the many different space and time scales, and the different mechanical and kinematic models.

Task 5 will be devoted to Diffusion, and Task 6 to Coordination.

This is a large, ambitious project (budget double of the mean project in ANR blanc), but its size can be justified as follows . Developing Task 1 alone would not answer a major question: is the Psathopyrgos fault able to generate large earthquakes, or does it creep intermittently, relaxing strain? Thus Task 2 is requested to answer this question. On the other hand, dismissing Task 1 would leave mostly unresolved the geometry and present seismic/aseismic activity of the threatening Psathopyrgos fault, and Task 2 alone would not bring much information on it. Thus, Task 1 and 2 together guarantee a complete coverage of the proper time and space scales (see Fig. 7). Task 3 is then requested for introducing 3D mechanical modelling of the reported processes. The probabilistic approach of Task 4 is a logical, and possibly only way to integrate the results of previous Tasks into one or several consistent models for assessment of earthquake likelihood in the area.

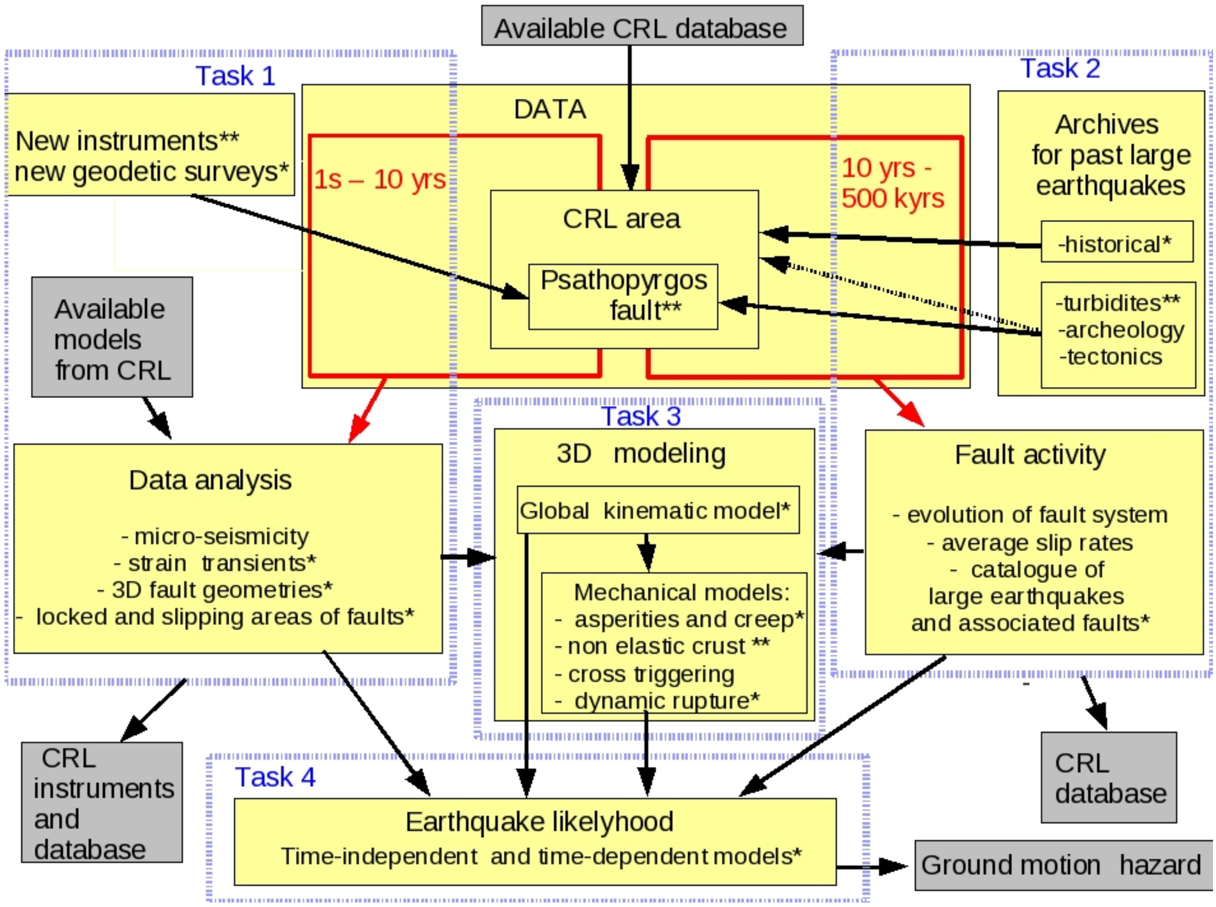


Figure 6 : Schematic presentation of Tasks and their interactions in SISCOR

In grey: activities outside the project, providing input to, or getting output from the project. Stars denote larger manpower and budget effort.

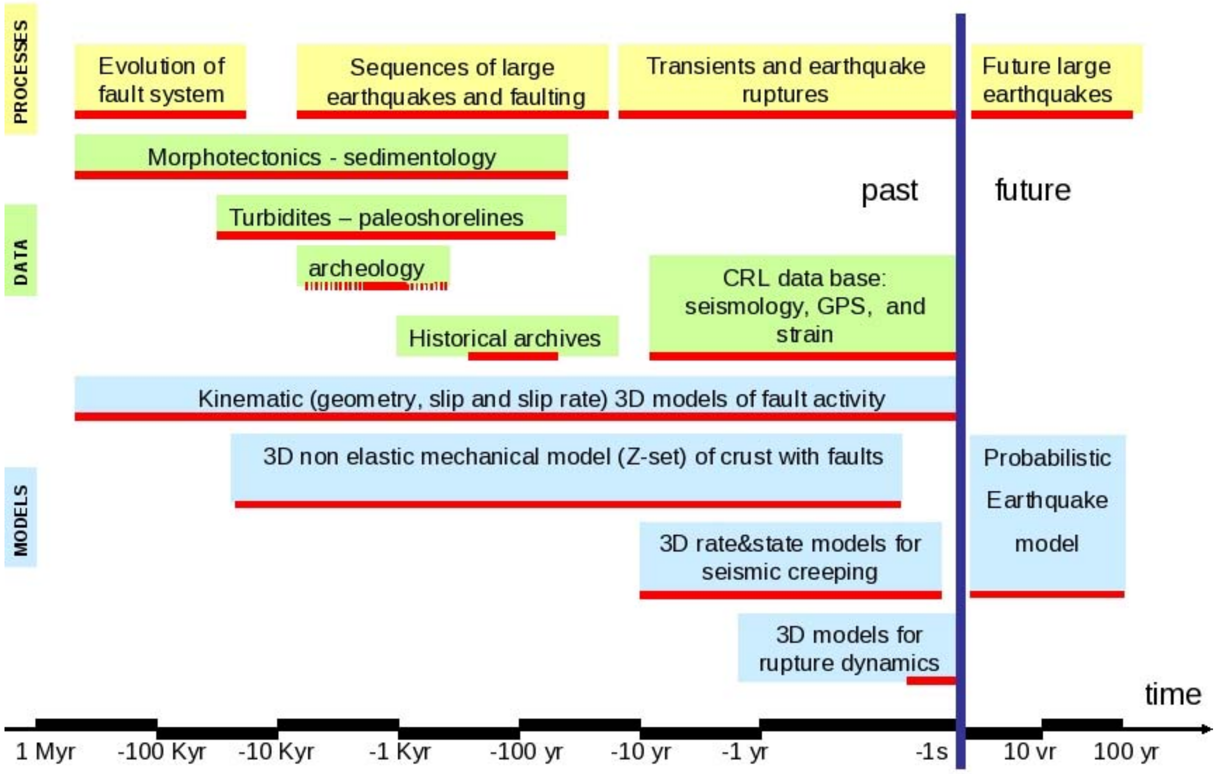


Figure 7: Time scales for processes, data, and models

Task 0: Coordination

Task1: Observation and kinematic analysis of short term processes (second to decade)

Task 1.1: improving monitoring arrays and surveys for medium/short term data and structural images

T1.1.a. Improving the seismic array near the Psathopyrgos faults: 3 new stations

T1.1.b Improving the accelerometer array: 3 new accelerometers

T1.1.c Improving the cGPS array near the Psathopyrgos fault: 10 new stations

T1.1.d Improving the strain array near the Psathopyrogs faults: 2 new borehole tiltmeters

T1.1.e Repeated GPS surveys in the CRL area

T1.1.f Fusion of GPS data and InSAR images

Task 1.2: analysis of seismic and strain data

T1.2.a seismogenic structures (relocation with crosscorrelations, tomography)

T1.2.b micro-seismic sources ; distribution space-time magnitude

T1.2.c Changes in seismic velocities from noise correlation studies

T1.2.d aseismic transients; detection, kinematic modeling

T1.2.e: 3D kinematic modeling of secular strain from GPS

T1.2.f: detection and analysis of cross-triggering between seismic and aseismic transients

T1.2.g determination of a consistent 3D fault model with locked and creeping patches

T1.2.h: kinematic modeling of rupture in case of earthquake with M>5.5

Task 2. Data gathering and analysis for long term processes (large earthquakes, centuries to holocene)

Task 2.1 Offshore sedimentary archives (turbidites) for large earthquakes

T2.1.a data acquisition: seismic and coring survey

T2.1.b data analysis: sedimentary event identification and dating

T2.1.c probabilistic characterization of causative faults: location, size

Task 2.2 Cumulative deformation and 3D fault geometry from tectonics

T2.2.a Dating of uplifted marine deposits and high stand terraces.

T2.2.b Dating uplifted ancient harbour dock

T2.2.c Detailed mapping of the Psathopyrgos fault and adjoining faults

Task 2.3 Historical archives

T.2.3.a gathering of existing and new archives for historical earthquakes

T.2.3.b probabilistic characterization of causative faults: location, size

Task 2.4 Homogeneous catalogue

T2.4 building a homogeneous earthquake catalogue

Task 3: 3D kinematic and mechanical modeling of processes at various time-scale

The short, medium and long term data analysis of Task 1 and 2 will provide the observational constraint for kinematic and mechanical modelling of the underlying processes.

Task 3.1 building a 3D kinematic model of active faults

Task 3.2 modeling of seismic rupture propagation on segmented normal faults with slip weakening laws

Task 3.3 modeling of crustal deformation based on the 3D model of 1.2.f with non elastic rheology

Task 3.4 assessing probabilities for cross-triggering between moderate to large earthquake

Task 3.5 modeling of multiplet activity with Rate and State friction laws

Task 4: Assessing probabilities of earthquakes

The data and models above will be used for probabilistic estimates of future seismicity.

Task 4.1 construction of logic tree for standard, time –independent seismogenic sources

Task 4.2 construction of a logic tree approach for time-dependent, fault-related seismicity

Task 4.3 integration of earthquake triggering effects in the logic tree

Task 4.4 comparison of the predicted seismic activity for the various approaches

Task 5: Dissemination

3.2. Coordination du projet / Project management

A steering committee will be composed by the coordinator with the Tasks and Sub-Tasks coordinators.

Kick-off meeting

It will be held in Paris, with all partners.

Initial Field trip

Before month 3, a field trip with all partners will be organized to the Aigion/Patras region. It will concern all the activities: tectonics, geophysical instrumentation, meeting with Greek partners (Univ. Patras and Athens,).

Project reports, 6 months

Contractual reports

Field activities:

The responsible for the activity will inform the partners about dates and purpose of the trip, so that different teams may be able to meet on site. At the end of each trip, a short report will be written.

Special meetings

Two important meetings involving all partners will be organized, related to the activities of Task3.1 and Task4.1.

Creation of a project web page on the CRL web site

The project and its main objectives will be presented on the CRL web site.

Yearly meetings

Contractual meeting will be organized every year

Tasks coordinators:

Each task has a coordinator , in charge of focussed meetings and communication within the Task activity, and coordination with the coordinator, the steering committee, and to other groups.

Links and coordination/collaboration with other projects and institutions:

The coordinator and steering committee will represent the project for :

- CRL activities
- Greek academics (University of Athens, University of Patras, National Obsevatory Athens)
- running ANR project "LINES" (coord. J. Chery) for laser seismometer and tiltmeter prototype testing
- running ANR project "ASEISMIC" (coord. D. Marsan) for inferring strain transients from space-time microseismicity.
- running RESIF French initiative for EPOS*: the mobile component of EPOS will be used for temporary experiments in CRL.
- Archeological "Helike Project " (http://www.helike.org/)
- end-users in Greece : OASP/EPPO (Earthquake Planning and Protection Organization); Public authorities of Aigion and Patras; SATWAYS (Greek company with expertise for disaster real-time monitoring and response planning), GEFYRA/VINCI (operators of the Rio-Antirio Bridge).
- European project "NERA" (subproject NA7) developing networking between European fault system observatories, including CRL (submitted dec 2009).
- response to future EPOS-related EC calls

**EPOS: European Plate Observatory. It is a large European Research infrastructure project (ESFRI), to which France is particpating, which will enter its 4 years preparatory phase in 2010 (www.epos-eu.org/).*

Consortium Agreement:

A cooperation agreement is under negotiation between CNRS, University of Patras, and University of Athens, for commitment to maintain and develop CRL-related monitoring facilities and open data-bases, as well as for research. This is a first step towards integration of CRL within the EPOS road map.

3.3. Description des travaux par tâche / detailed description of the work organised by tasks

3.3.1 Task 1 - Observation and kinematic analysis of short term processes (second to decade)

Task 1.1: improving monitoring arrays and surveys for medium/short term data and structural images

Task coordinator Hélène Lyon-Caen, ENS

This task will provide a complement to the existing instrumental data base within CRL, and thus allow a very significant step in the resolution of the activity of the Psathopyrgos fault.

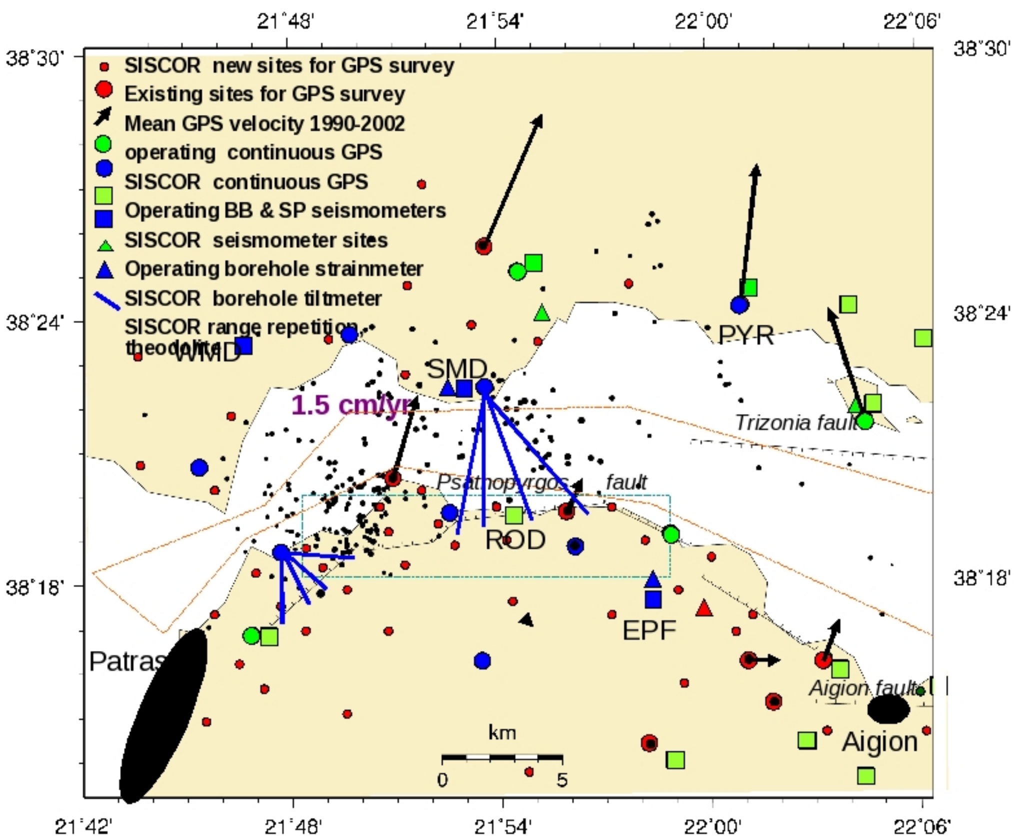


Figure 8: Monitoring of the Psathopyrgos fault. Blue symbols: planned SISCOR sites. Small red dot: repeated GPS points. Black dots: epicentres of the Nov-Dec 2002 seismic swarm (Bernard et al., 2009). Orange polygon: area for planned offshore seismics and coring; blue dotted rectangle: area for on-land paleoseismic and tectonic studies.

T1.1.a. Improving the seismic array near the Psathopyrgos faults: 3 new stations

H. Lyon-Caen, P. Bernard, A. Deschamps, A. Nercessian, M. Aissaoui

The CRL seismological array is presently centred on the Aigion area and, as shown on Figure 2, the Psathopyrgos fault area is poorly covered. Although the inclusion in the CRL database of data from 2 stations run by the University of Patras (UPR located just northeast of Patras and EFP northeast of Nafpaktos), and one run by the Athens university (ROD) helps to locate the largest events in the Psathopyrgos area, the installation of 3 new seismological stations with short period sensors (Figure 2 and 8) is necessary in order to reach a detection level and location accuracy as good as around Aigion. We thus plan to install:

- one station (WMD) located above the NW end of the Psathopyrgos fault, on the northern coast. As it is a rock site, a surface installation is enough.
- one station to the north, centred on the fault, on the Mornos delta. (SMD) Because of the soft sediments, a borehole is requested.
- one surface station to the SE, near the Lambiri fault scarp (EPF)

Real time telemetry will be installed for these stations (GPRS, or ADSL - if necessary with freewave link)

T1.1.b Improving the accelerometer array: 3 new accelerometers

P. Bernard, M. Aissaoui

Three accelerometers will be installed in the western area (see Figure 2, top right, red dots, colocated with SP seismometers), in order to have a proper coverage of the Psathopyrgos fault. Indeed, the seismic waves from a moderate to large earthquake will saturate the SP and BB records. Only the sensors will be charged to ANR, the budget for the recorders being planned from other sources.

T1.1.c Improving the continuous GPS array near the Psathopyrgos fault: 8 new stations

P. Briole, F. Rolandone, O. Charade, A. Nercessian

Three permanent GPS receivers (Efpalion on the N, Patras to the SW, and Lambiri to the SE) are already operated within 10 km of the Psathopyrgos fault. For resolving in time and space any significant creep transient on one or several of the 3 major segments of the fault (Psathopyrgos sensu stricto, Rio-Antirio, Lambiri), the 3 GPS points are clearly not sufficient. We propose a qualitative jump in the resolving capabilities, with the installation and operation of 8 additional cGPS stations, on and surrounding the fault (Fig. 8). In that way, each subsegment is controlled by about 4 GPS in its vicinity. One receiver is already bought but not installed, 3 will be brought and installed by University of Patras, and 4 new are asked for within the present project.

T1.1.d Improving the high resolution strain array near the Psathopyrgos faults: 2 new borehole tiltmeters

P. Bernard, Ch. Brunet, S. Lambotte

For transient processes in the period range 1 hour to weeks or months, cGPS measurements are at least 100 times less resolving than borehole strainmeters. Two borehole strainmeters are in the neighbourhood of the Psathopyrgos fault, one in the Trizonia island (TRI), 20 km from the fault surface, and one in Monasteraki (MOK), above the fault, at the distance of 6 km (see Fig. 2). This distance ratio makes the MOK station in average 30 times more sensitive than TRI to strain transients on this fault. Hence, many transients or slow earthquakes could be recorded at only one station (MOK), and consequently would not be constrained. Two additional sites for strain measurement could greatly improve the identification and allow the modelling of such transients.

The global cost of one borehole strainmeter site, like at TRI and MOK, is around 120 keuros. We thus propose here to use much cheaper borehole tiltmeters, with a resolution degradation of a factor of 10, thus still 10 times more resolvent than cGPS. One will be installed in the seismometer borehole of SMD), the other in a dedicated borehole close to site EPF (Fig. 8).

Such an array, with 4 strain or tilt measurement sites, will imply a qualitative jump in the detection and resolution of small scale creep transient.

T1.1.e Repeated GPS and distance surveys in the CRL area

P. Briole, F. Rolandone, T. Lebourg, O. Charade, A. Nercessian

We will reoccupy the existing first and second order points of the Corinth rift GPS surveys (about 8 and 20 respectively), plus those specific to the 3HAZ project, and create and measure more second order points, in order to better constrain the horizontal and vertical displacements across and around the Psathopyrgos fault (see red dots in Figure 8). Three GPS campaigns are planned during the project, once every year.

In addition to the GPS, using a geodimeter available at GEOAZUR, distance measurements will be made from the northern coast (*i.e.* the new cGPS site to be installed at the southern edge of the Nafpaktos Delta) to reflectors installed on the south coast across the Psathopyrgos (some of them already exist). (see blue lines in Fig. 7).The accuracy of such measurements is about 10^{-6}, thus 5 mm for typical distances of 5 km, but our experience of similar measurements at the Piton de la Fournaise volcano between 1993 and 2000 has shown that the measurements can be used in differential between one reflector and its neighbours, leading to relative accuracies of about 1 mm, thus comparable to GPS or better. Great care will be taken for distinguishing the tectonic fault movements from the gravitational sliding of the numerous landslides on the steep slopes of the Psathopyrgos footwall (see Lebourg *et al.*, 2009). A similar survey will be done for the Rio-antirio fault, with a shooting site at Rio (new cGPS site), 3 km NW from the fault scarp, and reflectors on its footwall. This should significantly improve the space resolution of the long term strain and large creep transients.

T1.1.f Fusion of GPS data and InSAR images

P. Briole, coll. P. Elias

ALOS (Lband) and ENVISAT (Cband) SAR interferograms are currently produced in the framework of an ongoing PhD thesis (P. Elias, cotutelle Univ. patras/ENS). These interferograms will be analyzed together with the GPS observations velocities (or motions). InSAR data, once corrected for the troposphere, are expected to provide an accurate mapping of the vertical changes.

Task 1.2 : analysis of seismic and strain data

coord. H. Lyon-Caen

T1.2.a seismogenic structures (relocation with cross-correlations, tomography)

H. Lyon-Caen, A. Deschamps, S. Lambotte

In the framework of the ANR project Cattel@CRL, completed in 2009, the whole CRL database (2000-2008) has been cleaned and relocated using a strategy of classification of events into families of multiplets (that is events whose waveforms are similar and thus are clustered and in general define a unique rupture geometry). Combining high resolution relocations with polarity information allows to define major activated fault planes (e.g. Pacchiani, 2006; Pacchiani and Lyon-Caen, 2010; Lambotte et al., in prep). Such a study will be completed for CRL data and extended towards the west including already existing data from Patras University and new data from new instruments installed at the beginning of this project.

Seismological records at most of the stations exhibit late arrivals between P and S waves: the use of multiplet at a single station and the precise relative location of the sources will help to interpret these late arrivals and allow the determination of pieces of interfaces with strong velocity contrast in the upper crust. The 3D tomographic model proposed by Latorre et al. (2004) or Gautier et al. (2006) will be used to locate these interfaces.

T1.2.b micro-seismic sources and space-time-magnitude distributions

O. Scotti, H. Lyon-Caen, P. Bernard, P. Dublanchet

The cleaned and relocated CRL catalogue will be the basis for space-time analysis in the CRL region.

- The size and geometries of the small faults activated by seismic multiplets will be investigated, with a particular attention to source size from corner frequencies, and to the possible overlap between seismic asperities, for determining their mode of interaction.
- The possible triggering of microseismicity by surface waves from moderate to large regional earthquakes will be investigated.
- If the noise level of stations allows it, we will attempt to scan the CRL continuous records for tectonic tremors.
- We will attempt to characterize the seismic behaviour of each major fault segment based on a statistical analysis of the seismicity. In order to achieve this goal it is necessary to somehow associate each individual event to a given fault. Gutenberg-Richter laws will then be calculated and quantitatively compared for the different identified faults, for different depth range and time periods.
- We will also characterize the seismic behaviour of the volume between large faults.
- The CRL catalogue provides a unique opportunity to test if scaling laws hold over the entire magnitude range (1.2 to 6.). For this reason, b-values will also be computed for

different magnitude ranges and checked for statistically significant differences. If such differences are identified, their causes will be explored and different hypothesis will be tested and considered when estimating earthquake likelihoods in Task 4.

T1.2.c Changes in seismic velocities from noise correlation studies

A. Deschamps, L. Stehly

Cociani et al. (2010) have found changes of physical characteristics in the vicinity of the main sources during the 2001 seismic crisis. Such study will be extended to more recent data (2009 crisis if possible with the available data). In case of success, real time data will be systematically analysed to follow the velocity change in the central part of the network.

T1.2.d detection and classification of aseismic transients

P. Bernard, A. Canitano

A systematic search for transients will be conducted on the strain/tilt records. First, external influence of atmospheric pressure and sea level will be removed by correlation studies, then a catalogue of the significant remaining anomalies will be created, and classified according to their duration and waveform.

T1.2.e 3D kinematic modeling of secular strain from GPS

P. Briole, F. Rolandone, P. Bernard

The objective it to constrain locked/unlocked large scales patches with 3D models of dislocations in an elastic half-space. This will be done at two scales: the CRL area, using the existing GPS data, and at the refined scale of the Psathopyrgos fault, when the new dense GPS data will be available.

T1.2.f: detection and analysis of cross-triggering between seismic and aseismic transients

P. Bernard, A. Canitano

The catalogue of strain anomalies (see above) will be compared to the seismic catalogue, for the detection of statistically significant correlation, and the quantification of seismic/aseismic coupling. The latter will provide a way to locate the sources of the strain signals, and constrain their kinematic models. The triggering correlation with tide will also be carefully investigated, taking benefit of the accurately measured local tidal strain.

T1.2.g: determination of a consistent 3D fault model with locked and creeping patches

Lyon-Caen, Briole, Deschamps, Bernard

All data and models obtained above will be cross-analyzed and integrated to produce an updated, consistent description of the geometry of faults, of their activity and of the major slipping and locked patches, at the time scale of decades.

T1.2.h: kinematic modeling of rupture in case of earthquake with M>5.0

P. Bernard, A. Deschamps, H. Lyon-Caen, coll. IRSN

In case of a significant earthquake, the teleseismic, regional broadband, and local accelerometric records will be analysed, and modelled with kinematic source. The broadband frequency range of the event will be represented by a k-square kinematic source if M>5.5 (Ruiz et al., 2007).

3.3.2 TASK 2 - DATA GATHERING AND ANALYSIS FOR LONG TERM PROCESSES (CENTURIES TO HOLOCENE)

Task 2.1 Offshore sedimentary archives for large earthquakes (shock-induced disturbances and specific layers)

Ch. Beck; J.-L. Schneider, S. Schmidt, M. Ford; coll : A. Hubert-Ferrari, De Batist

The sedimentary infill of the Gulf of Corinth represents an essential local to regional paleoseimic archive (Van Welden, 2007) especially because suitable onshore paleoseimic sites are lacking. With adequate density of data (seismic-reflexion profile grids and associated cores), it would yield both time and space distribution of earthquake-related features, thus contributing to the estimation of *recurrence time intervals* and of *displacement surfaces*.

T2.1.a data acquisition: seismic and coring survey

Using high and very high seismic reflexion imaging, seismo-turbidites (and especially the upper "homogenite" layers) can be detected starting from a 20 cm-thickness, and thus traced and analyzed in 3D with a dense grid of profiles. Detailed bathymetry (using multibeam) adds information concerning the most recent ruptures and possible co-seismic disturbances. The offshore-seated faults, as well as the offshore sections of Eastern Helike, Psathopyrgos, and Rion-Antirion Faults (Fig. 1), are our main targets.

2000 km of seismic lines should be acquired, summing up GEOPULSE pinger profiles and single channel CENTIPEDE sparker profiles, all mainly orthogonal to the major faults, with few axial (parallel) profiles for inter-correlations and calibrations. A 300 m penetration is expected with high resolution equipment, and 50 m for very high resolution device, which means a possible 100 to 150 kyr archive following eastern Corinthos Gulf results (Van Welden, 2007).

Coring survey should be divided into:

- short gravity coring, using a 90 mm-diameter UWITEC corer; a set of 25 to 30 cores (1.5 m mean length) – without sediment/water interface disturbance - is necessary to detect and characterize the most recent events, especially the historical ones; they permit a down-hole extrapolation back to several millennia Before Present;

- longer (6 to 9 m) piston coring (4 to 6), to ensure a long term archive in selected sites. They can be picked either using a local small oceanographic ship equipped with a Küllenberg system, or a portable UWITEC platform trailed from France or Belgium.

T2.1.b data analysis: sedimentary event identification and dating

The chronological control of cored successions should be based on calibrated A.M.S. ^{14}C dating (on vegetal organic debris or dispersed OM) combined with measurements of paleo-intensity of the magnetic field and of its secular variation, and, for the upper part of the short cores, on ^{210}Pb decay profiles (last century), and ^{137}Cs-rich levels (Atmospheric Nuclear Experiments and Tchernobyl event). The later ones yield an estimation of present day sedimentation rates which can be tentatively extrapolated back to a few centuries B.P.; they may also directly indicated recent earthquake disturbances (Arnaud et al., 2002; Beck, Feuillet, Reyss, et al., 2009)

T2.1.c probabilistic characterization of causative seismic faults: location, size

The sedimentary signature of the known historical earthquakes (about 30 reported with M>6 since 1700) in the whole Corinth rift could allow to calibrate, in a probabilistic way, an empirical law giving the distance and magnitude dependence of the threshold for the triggering. of turbidite deposits in the western rift.

Task 2.2 Cumulative deformation and 3D fault geometry from tectonics

M. Ford, A. Hubert Ferrari, J. Charreau. Collaboration: N. Palyvos (Harokopio University, Greece), D. Pantosti (INGV, Rome).

This task will provide data complementing the on-land paleoseismological studies conducted by the INGV group on the Psathopyrgos fault (e.g., Palyvos et al., 2008), to retrieve evidence for large paleo-earthquakes during the last 2500 years, as well as coastal uplift and subsidence rates.

T2.2.a Dating of uplifted marine deposits and high stand terraces.

Dating of uplifted marine deposits and high stand terraces. Fault surface exposure using cosmogenic nucleides (coll: P.H. Blard, CRPG).

Palyvos et al (2007) describe marine platforms and rare notches along the coast in the immediate footwall of the Psathopyrgos fault. These define a series of paleoshorelines that are interpreted as recording five major earthquakes in the last 2000 years.

Goal: To obtain footwall uplift rate estimates in the target area from which fault slip rates can be derived.

T2.2.b Dating uplifted ancient harbour dock

coll: D. Katsonopoulou

Remains of an ancient man-made structure has been discovered near the coast at the village of Lambiri, and could be part of docks from an ancient harbour (D. Katsonopoulou, personal communication). Analysing this structure for datation, and measuring its level above present sea level would provide an important, accurate measure of mean uplift rate of the site, and hence constrain the fault slip rate of the neighbouring Lambiri fault. The archeological field work will be conducted by D. Katsonopoulou (Director of the Helike Society), specialist of the region. Field surveys are planned in 2011, for selecting the targets for excavation; the latter will be done in 2012, when the permit is obtained.

Beside this main activity, the existing archaeological evidence for large earthquakes (through damage and repairs traces) since the bronze age in the Patras-Aigion area will be critically analysed and interpreted.

T2.2.c Detailed mapping of the Psathopyrgos fault and adjoining faults

Collection of geometric, kinematic and stratigraphic offset data across the coastal and inland fault system. High resolution mapping and sampling paleoshorelines in the immediate footwall of the fault.

Goal: To define the 3D geometry of the Psathopyrgos and adjoining faults, fault linkage, distribution of cumulative displacement. Data will used in Task 3.1 to construct a 3D geometrical model of the active fault system.

Task 2.3 Historical archives

Scotti, LyonCaen, Bernard – coll. Ext: Stiros, Ambraseys, Albini

The construction of the most complete historical and instrumental earthquake catalogue is the basic ingredient to earthquake forecast models. The aim of this project is to search for new records in yet unexplored archives in order to improve the number of individual macroseismic data points for at least the largest events.

T.2.3.a gathering of existing and new archives for historical earthquakes

Much of the archival material needed, including detailed accounts of macroseismic effects are published (N. Ambraseys, Cambridge Un. Press, 2009). According to N. Ambraseys, for the period before 1800s there is almost nothing to be found in Greek sources. For the 19th c. press reports have some useful but very partial information. Nevertheless, N. Ambraseys proposes to investigate this issue further, within this project, as external collaboration. Indeed, according to Paola Albini (personal communication) some additional documents for the period before 1800s may be found in the archives of Venice, Italy. In particular, for the 1462 earthquake, which destroyed the city of Lepantos (Nafpaktos) (Guidoboni and Comastri, 2002), this may provide critical information for the activity of the Psathopyrgos fault. P. Albini proposes to investigate this issue further, within this project, as external collaboration.

It is thus worth trying to investigate this issue and to attribute some of the budget to the archival search. An effort will be also dedicated to the estimate of Ms from medium period instruments for events before 1955, which will improve the knowledge of the intermediate magnitude events, in particular for the 1917 event close to the Psathopyrgos fault..

T.2.3.b probabilistic characterization of causative faults: location, size

The ultimate aim of this task is to reanalyze the macroseismic database available for the region in order to apply recently developed techniques for locating historical earthquakes and for estimating their magnitudes (Baumont and Scotti, 2008; Bakun and Scotti, 2005). The hope is to be able to attribute each earthquake of M>5.5 to a causative fault (or, in case of several candidate faults for one event, to asses their respective probabilities) , and thus improve the knowledge of the seismic history of each individual fault segment, an important ingredient for the calculations of TASK 4.

Task 2.4 Homogeneous earthquake catalogue

Scotti, Lyon-Caen

The historical seismicity catalogue will be complemented with the instrumental catalogues available for the region (NOA and CRL-region) and with the paleoseismological studies. An homogeneous magnitude will have to be computed for the catalogue. Spatial and temporal completeness will also have to be addressed. It is anticipated that the magnitude of completeness will rise from M 1.2 in the CRL study area (Wyss et al., 2008) to M~3 where only regional networks have been operating. An important aspect that will be considered in this project is the estimation of uncertainty in location and magnitude for each event of the catalogue, in particular for the regional and historical events.

3.3.3 TASK 3 - 3D KINEMATIC AND MECHANICAL MODELING OF PROCESSES AT VARIOUS TIME-SCALE

Task 3.1 building an initial 3D kinematic model of active faults

M. Ford, H. Lyon-Caen, P. Briole, P. Bernard, O. Scotti, A. Deschamp, S. Lambotte

- Firstly, a 3D geometrical model of the fault network in the target area will be constructed using a geomodelling package and 3D database, integrating results from tasks 1 and 2: onshore and offshore geosciences data (digital elevation models, structural and stratigraphic data, maps and cross sections, seismic data, seismic lines) as well as multiplets and other seismic data. Data can be associated with different levels of uncertainty and models will be tested for coherence. A hierarchy of fault surfaces will be established within the model(s). Through their construction, these models should generate new ideas and challenge established concepts. The model-database will be constructed and adapted throughout the project and will act as a medium to facilitate and generate discussion between research groups.

- Secondly, long term slip rates and medium term creeping rates (including locked patches) provided by tasks 1 and 2 will be specified for each fault and integrated into the 3D fault model above. A tight constraint will be the moment balancing, which is the requirement that over the long term the displacements from the earthquakes sum to the observed slip rate all along the faults. As the slip rates will depend on the relative weights provided to the various input data, due to their own uncertainties (fault uplift, "turbidite" earthquake catalogue, historical earthquakes, GPS rates, fault lengths, …), one may end up with several, different fault activity models, the respective probability of which will be estimated.

Task 3.2 modeling of seismic rupture propagation on segmented normal faults with slip weakening laws

P. Favreau, J.-P. Vilotte

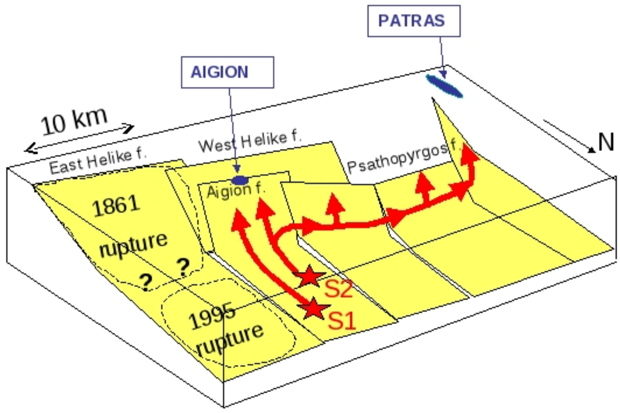


Figure 5 : sketch of possible dynamic seismic ruptures, through single (S1) or multiple (S2) fault segment(s), resulting in final magnitude about 6 for S1 and 6.7 for S2 (+-0.2).

The simulation of large events in the CRL area requires rupture dynamic simulation on multiple, non-coplanar, segments including inter-segment damage zones under various initial mechanical conditions (initial stress distributions).

- We will extend the existing 2D Spectral Element code (Festa et al (2006) and Ampuero et al (2009)), for rupture dynamics on a non coplanar fault segments to 3D, including slip and rate-and-state friction together with simple bulk dissipative damage rheology in the fault relay zones. Such numerical simulations are not expected to provide resolution below a length scale of a couple of kilometres. Special care will have to be taken to account for potential rupture extension up to the free surface, and several comparisons with the work of Wolf et al. (2008) will be conducted.
- Based on numerical scenarios and pre-stress distributions, we will perform the analysis of the conditions for large earthquakes (dynamic cascade through more than one segment) and characterize the low wavelength slip / segment boundary pinning - for magnitude estimate. The fault geometries and initial conditions will be inferred from the results of Tasks 1 and 2.

In case of a moderate to large event, accelerometric records will be fitted through dynamic modeling.

Task 3.3 Modeling of crustal deformation based on the 3D model of 1.2.f with non elastic rheology

F. Rolandone, H. Lyon-Caen, P. Briole

The goal is to build a 3D model of the area (~40x30x30 km) where faults will be embedded in a 3D medium and to analyse its evolution over about 10Kyr. The mesh will allow a 3D description of the rheology and of interfaces on which various friction laws could be defined. Initial conditions will be defined by the tectonic loading but some "steady state" will have to be found before starting experiments. Large seismic asperities and creeping zones will be defined from the model built in Task 3.1. We want to realize deformation experiments over a time scale of 1000 to 10000 yr that will thus include few hundreds of large earthquakes. This modelling will be important for testing geometrical/mechanical hypothesis as well as proposing a consistent evolution model of the fault network.

We will use the 3D code Z-set (known also as Zebulon, http://zebulon.onera.fr) developed partly by the mechanic group of Ecole des Mines and ONERA and freely available for academic use. This choice is guided by the fact that Ecole Normale has already developed an expertise in the use of this software for geophysical problems (through project Opossum financed by ANR-Cattel) and will be able to directly interact with Jean-Didier Garaud, one of the computer expert of this code.

Task 3.4 assessing probabilities for cross-triggering between moderate to large earthquake

P. Bernard

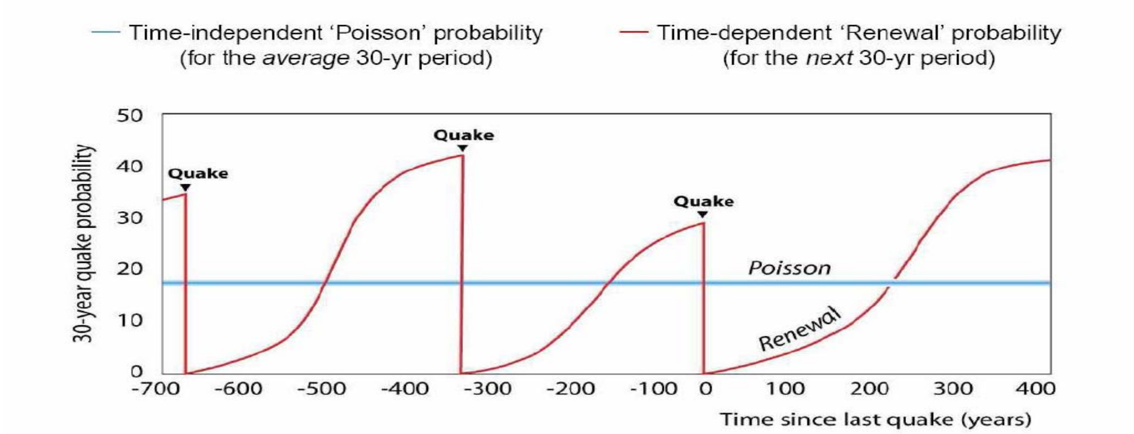
The space-time distribution of the largest historical earthquakes (M>6) of the whole rift of Corinth shows clear clustering in time (less than a few years) and space (less than 20 km). This space-time correlation will be analyzed to infer simple probabilistic laws for triggerin (generalized Gutenberg-Richter with Omori law) which will be assumed to be valid in the CRL area for future scenarios of seismic cascades.

Task 3.5 modeling of multiplet activity with Rate and State friction laws

P. Favreau, P. Dublanchet, P. Bernard

The mechanical behaviour of small (1 m – 100 m) seismic asperities on kilometric, dominantly creeping fault planes, with geometries inferred from observations, will be modelled with "rate and state" (R&S) formulation in 3D. We will investigate the role of the R&S parameters on isolated as well as on interacting asperities. We will in particular focus on the interaction and overlapping of successive ruptures, and the production of "repeaters". The response of asperity populations to reported stress transients and steps will also be investigated, and compared to the standard, simple 1 D Dieterich model for aftershocks. The resulting space-time-magnitude distribution of seismicity will then be compared to the observation to constrain the range of plausible R&S parameters. The response of asperities to tidal strain and seismic waves will also be modelled, for comparison to the observations.

3.3.4 TASK 4 - ASSESSING PROBABILITIES OF EARTHQUAKES



The data and models above will be used for probabilistic estimates of future seismicity. We will address here three main questions for estimating the earthquake hazard, applied to the CRL area..

- how do earthquake likelihood estimates compare between approaches that consider seismicity as being concentrated on the main active faults, instead of being diffused over seismogenic sources as in standard approaches.
- how is earthquake likelihood affected when the recent seismic history of each major fault is factored in, or/and when the aseismic component is accounted for?
- how is earthquake likelihood affected by taking into account the possibility of delayed, cascade triggering of large earthquake by a first one ?

We recall that the estimates of ground motion hazard, which can be obtained from the combination of the above earthquake likelihoods with attenuation laws, will not be developed within the present project.

We will implement both the classical approach based on the standard "seismogenic sources" definition and on the use of Gutenberg-Richter time-independent earthquake statistics, and the alternative approach based on the use of faults and time-dependent seismicity models (Fig. 9). In order to capture the range of possible interpretations and modelling that will be proposed in the Tasks 2 and 3, a logic tree methodology will be implemented. The construction of the logic-tree will be an important deliverable of this task and will include at least three main branches as explained in Task 4.1, 4.2 and 4.3.

Fig. 9. Time-independent (Poisson) likelihood models will be tested as well as time-dependent forecasts that use stress-renewal assumptions to condition the event probabilities on the date of their last occurrence (at least for the most active faults.

Task 4.1 construction of logic tree for standard, time –independent seismogenic sources

Scotti, Lyon-Caen

We will consider first the simplest time-independent model with a standard "seismogenic source" approach where the expected earthquakes are located in various contiguous areas (or "sources"), each with a specified, mean seismic activity (Gutenberg Richter law). We will test different geographical definitions of the seismogenic sources, different catalogue durations, different magnitude range statistics, etc, according to the results of the previous Tasks. The effect of the various uncertainties and weighting between these informations will be integrated into a logic tree.

Task 4.2 construction of a logic tree for time-dependent, fault-related seismicity

Scotti, Lyon-Caen

The probabilities of future large ruptures on identified faults (probability of an event exceeding some magnitude in a specific time range, and on a specific fault) will be inferred from the various earthquakes archives gathered and analyzed in the project (historical, archeological, geological), as well as from the predictive kinematic or mechanical models in the project, constrained by observations (present strain rates, areas of creep, areas of locked asperities, 3D fault geometries, geological slip rates, …) (see Task 3.1). The integration of all these probabilities into a common model will be done by the construction of a logic tree which will integrate expert assessment for weighting the relative probabilities of the many branches of the tree.

One of the difficulties to overcome comes from the non-independent character of some information or model sets, which will make the definition of the branching structure not trivial.

Another difficulty to be dealt with concerns to the integration of moderate and micro seismicity, which is not related to the major, identified faults.

Task 4.3 integration of earthquake triggering effects in the logic tree

Scotti, Lyon-Caen, Bernard

The possibility for triggering of cascade earthquakes will be formulated for the logic tree approach above, based on the triggering models derived in task 3, and integrated to it. This will be based on the simple triggering intensity model (T3.4), and on the statistical results of the Z-set/Zebulon mechanical model (T3.1). Indeed; the later will include realistic, delayed triggering effects and produce long synthetic earthquake catalogues which can provide probability estimates of cascade events.

Task 4.4 comparison of the predicted seismic activity for the various approaches above

We will compare the statistical results of three approaches (time-independent, time dependent with no triggering, time dependent with triggering). We will estimate in particular the probability gains related to the time-dependent approach, and to the inclusion of cross-triggering.

3.3.5 TASK 5 - DISSEMINATION

- Scientific papers and congress for all Tasks
- PhD thesis IRSN/ENS (Tasks 1.2; 2.4; 3.1; 4);
- contribution to CRL data bases
- Communications to Greek local authorities (Aigion, Patras)
- Earthquake Probability Maps and local seismic zonation (from Task 4), reports for OASP/EPPO
- Communications to SATWAYS and GEFYRA/VINCI
- Communication to researchers in SHS in France and in Greece, for motivating new studies on the evaluation and improvement of communication between scientists and stake holders/public in the context of a medium term earthquake prediction.
- Communication of the archeo-seismological results to the Archeological community in Greece
- conferences for general public
- website pages for general public
- project scheme for permanent exhibition in the city of Aigion on local seismic Hazard

3.4. Calendrier des taches, livrables et jalons / planning of tasks, deliverables and milestones

TASK	DEL.	TITLE	RESP.	DATE
coord				MONTH
		Semestrial reports		6-12-18-24-36
		Annual project meeting and report		12-24-36
T1		8 new continuous GPS sites	ENS	6
		3 new seismometer sites	IPGP	6
		Telemetry for 3 seismometers	ENS	6
		2 new borehole tiltmeters	IPGP	6
		3 new accelerometer	IPGP	6
		GPS displacement surveys	ENS	2-17-33
		Theodolite range surveys	GEOAZUR	2-17-33
		GPS, seismic, and strain data of CRL	ENS	1 to 36
		Refined structural models of faults and interface at depth	EOST	24-36
		Space-time-magnitude characteristics of micro-seismicity	GEOAZUR	24-36
		Catalogue and models of strain transients	IPGP	36
		3D Maps of creeping and locked sections of faults	ENS	24-36
T2		High resolution bathymetry and seismic profiles	LGCA	12
		Cores 5 to 15 m	LGCA	12
		Offshore statigraphy and sedimentary analysis	LGCA	12
		Dates on core levels	LGCA	12
		Tectonic and stratigraphic maps of Psathopyrgos fault	CRPG	24
		Dates on syn-rift stratigraphy, faults and paleoshorelines'	CRPG	24
		Archives for historical earthquakes	IRSN	12
		Catalogue of large earthquakes 10 kyr-present	LGCA	12
		Slip rate on Psathopyrgos fault from archaeology	IPGP	18-30
		Probabilistic association of historical earthquakes to faults	IRSN	18
		Catalogue of relocated microseismciity	EOST	12-24-36
T3		3D kinematic model of active faults	CRPG	12-24-36
		Probabilistic models for cross segment dynamic rupture	IPGP	12
		Non elastic 3D model of the CRL area	ENS	24-36
		Characterization of the mechanics of local asperities for microseismicity	IPGP	24-36
T4		Probabilities of future earthquakes on faults	IRSN	12
		Probabilities of earthquake cascades	IPGP	12
		Logic tree for time independent hazard assessment	IRSN	24
		Logic tree for time dependent hazard assessment	IRSN	36
		Proposition of new seismic zonation for the CRL region	IRSN	36

T5		Scientific papers and abstracts to conferences	ALL	12 to 36
		PhD thesis (IRSN/ENS, IPGP, LGCA)		36
		Reports for end-users	IPGP	36
		Contribution to CRL web-site	ENS	12-24-36
		1 conferences for general public in Aigion	IPGP	30

- The main uncertainty for the data gathering concerns the offshore Task 2.1, because of possible problems with ship availability and favourable weather conditions.
- For the instrumentation, the major difficulty will be related to the borehole drilling in the soft sediments of the delta (risks of collapse); our own drilling experience in the area lead us to propose a significant budget to secure the work.
- Another uncertainty concerns the ability to find and date relevant archeological structures.

The probabilistic approach of Task 4 allows to adapt the work to the input data of Task1 and 2, and to the models from Task 3. Any difficulties with these data and models (quality, delay of production..) therefore do not alter the methodology, but changes the resolution of the hazard probability estimates. Once the logic tree is constructed, revising probabilities related to new data is easily incorporated for a revised hazard assessment. Three phases of input for the logic tree can be planned, related to new incoming data (at least from GPS and theodolite surveys).

In addition to the 4 plenary project meetings (kickoff, years 1, 2 and 3), we plan:

- before month 3, a meeting in Aigion will all participants: geologic/tectonic field trip, visit to instrumented sites, meeting with Aigion major, meeting with the Greek colleagues from Athens and Patras Universities.
- 2 special meetings, involving most of the participants, for Tasks 3.1 and 4.1. These meetings will allow the comparison, classification, and integration of the many observations and models.

4. STRATEGIE DE VALORISATION DES RESULTATS ET MODE DE PROTECTION ET D'EXPLOITATION DES RESULTATS / DATA MANAGEMENT, DATA SHARING, INTELLECTUAL PROPERTY AND RESULTS EXPLOITATION

The valorization of the results for the various end-users is listed below, linked to, and in continuation with ,the TASK5 Diffusion .

Science and Research:

- Scientific papers and international conferences
- feeding and expanding CRL data bases, with continuous records and surveys, and improving their free on-line access : these open data bases contain seismological, geodetic, geophysical, geologic, sedimentological, hydrogeological, oceanographic, and meteorological records. They may thus be useful for many communities of earth sciences.
- validation of 3D numerical codes for modelling fault and earthquake mechanics, to be applied for further studies in CRL or other seismic contexts.
- new expertise for seismically induced turbidite identification, to be applied in other offshore seismic regions.
- PhD thesis : the project developments and deliverables will lead to the definition and start of several new PhDs, during or after the project, in particluar: modelling of dynamic rupture in 3D for non-coplanar faults, seismic/aseismic processes on the Psathopyrgos fault, 3D Kinematic and Geometric Evolution of an active Normal Fault Network: Gulf of Corinth, Greece,.

- At a European level, the results of SISCOR will provide a firm basis for leading the fault-system observatory component of the EPOS initiative.

Hazard and Risk

In Greece:

- Hazard Maps will be refined and discussed with our Greek colleagues (Univ. Patras and Athens)
- End-users (1): contact will be maintained with local public authorities in Aigion and Patras

- End-user (2): reports for hazard, and in particular a new seismic zonation of the western rift of Corinth, will be presented to OASP/EPPO.
- End-user (3): communication to researchers from social science in France and Greece may motivate new studies for the evaluation and improvement of communication between scientists and stake holders/public in the context of a medium term earthquake prediction. The French sociologists B. De Vanssay, L. Colbeau-Justin (Univ. Bourgogne), and A. Ernst-Vintila (Univ. Aix-Marseille) expressed their interest to this topic of research (collaboration to the unsuccessful CORQUAKE project submitted in to ANR RISKNAT in 2009) .
- End-user (4) : hazard scenarios will be discussed with SATWAYS, for defining their interfacing with post-seismic crisis scenarios, as already agreed early 2009.
- End-User (5): hazard scenarios will be presented to GEFYRA/VINCI, operators of the Rio-Antrio bridge, with whom we already had positive contacts for that matter in 2009.

Generic:

- New methodological developments of the project will be integrated in ongoing and future projects at the "Institut de Radio-Protection et de Sureté Nucléaire" (IRSN) concerned with the evaluation of seismic hazard for nuclear installations.

Communication to various public groups

- Communications for the Association Française pour la Prévention des Catastrophes Naturelles (AFPCN)
- contribution to CRL web-site , for general public and earth scientists
- conferences for the general public in Greece and in France
- website pages for the general public (in Greek, English, and French)
- a project for a permanent exhibition in Aigion on Hazard will be proposed to relevant funding programs and agencies

5. Organisation du partenariat / consortium organisation and description

5.1. Description, adéquation et complémentarité des partenaires / relevance and complementarity of the partners within the consortium

The project requires a strong integration of the different approaches to hazard evaluation, involving very different disciplines and expertise: seismology, geodesy, geophysics, tectonics, sedimentology, statistics, history. This will be achieved by the tight coordination and multiple interactions between the partners of the project and the external collaborators.

To construct the project partnership, we started from a core group originating from the CRL projects (seismologists, geodesists, and geologists from ENS, IPGP, GEOAZUR, EOST and CRPG), and first developed a larger geological component, required for the offshore stratigraphic and sedimentological studies close to the Psathopyrgos fault (with new partners, Univ. Chambery and Bordeaux). A. Hubert-Ferrari, who contributed to the elaboration of the project, has moved this year from ENS to University of Liege; she will collaborate with C. Beck for the offshore sedimentological studies.

External collaboration with the Renard Center of Marine Geology (University of Ghent) was requested for its expertise in high resolution seismic reflexion acquisition, processing and interpretation. A long collaboration with L.G.C.A. (C.Beck) has been developed especially for investigation of active tectonic and seismicity control on sedimentation. Integration of sedimentological investigations within active tectonic research projects has been successfully performed in different sites (e.g. Sea of Marmara, Lesser Antilles).

For the on-land tectonic studies on the Psathopyrgos fault, the pioneering work by the INGV group (D. Pantosti, N. Palyvos, P. De Martini.) within the 3HAZ project (coord. P. Bernard) naturally led to the continuation of this collaboration within the present project. N. Palyvos has in the meantime moved back to Greece, and will be involved in the tectonic on-land studies.

At the heart of the project, the necessity for a time-dependent probabilistic hazard assessment, due to the context of medium term prediction, led us to invite researchers of IRSN into the project, as they are recognized experts in that field and were particularly interested for developing new methodologies.

In order to benefit from a powerful mechanical modelling software (Z-set/Zebulon), we included a collaborative work with J.-D. Garaud (ONERA) .

Two new additional foreign collaborations are integrated. First, the necessity for refined work on the archives of historical earthquakes led us to invite N. Ambraseys, one of the best experts world-wide, member of the Greek Academy of Sciences, to collaborate with us. Second, the opportunity of collaboration of Greek archeologists for constraining coastal uplift led us to define a common project with D. Katsonopoulou, responsible for the excavation in the area (in particular for the "Helike project").

To complement all this, we of course will maintain our collaboration with the Greek researchers of NKUA (Athenes) and UPATRAS, sharing instrumental facilities and data.

01 - IPGP

The seismological team of Institut de Physique du Globe de Paris (IPGP , http://sismo.ipgp.jussieu.fr) has developed its expertise on seismic source processes for many years, from the observational as well as numerical perspective. The participants (4 researchers and 2 engineers) of the team will contribute to several aspects of the project, mostly:

- **coordination:** the coordinator has already coordinated several EC projects in the rift of Corinth (P. Bernard)
- **simulation of asperity ruptures in their seismic cycle:** this is a starting activity (Phd thesis). (P. Favreau)
- **simulation of kinematic and dynamic rupture of faults.** This is a mature activity, steadily developed in the last 10 years (P. Bernard, P. Favreau, J.P. Vilotte).
- **installation of borehole seismometers and tiltmeters:** the team has experience in this activity, with several instruments installed in boreholes 150 m to 1000 m deep in the rift of Corinth, in the last 5 years. (P. Bernard, Ch. Brunet)
- **analysis and modelling of microseismicity and transient deformation:** this has been developed in the last 10 years, in particular on the data from CRL. (P. Bernard, A. Nercessian)
- **contribution to telemetry and Data Base of CRL data** (M. Aissaoui)

02 – GEOAZUR

Géoazur, (CNRS/IRD/University of Nice Sophia Antipolis research unit) have developed a good expertise of long term seismological and deformation observation for landslides and gravity motions as for earthquake studies in South America and Mediterranean area: seismic station installation and maintenance, waveform inversion, source characterisation, seismic cycle, strong motion simulation but also in seismic tomography and velocity model determination. Two Géoazur researchers involved in SISCOR project (A. Deschamps and T. Lebourg) have participated to previous programs on Corinth Gulf mostly in deformation and microseismicity observation. The participation of news researchers of the group allows including a broader experience (mainly on ambient noise analysis expertise) which will benefit to the program developing new method for data analysis.

The participants to SISCOR will contribute mainly in task 1, 3 and 5.

- Installation of seismometers (collaboration with IPGP and ENS).
- Analysis of micro seismicity (collaboration with IPGP and ENS)
- refined tomographic analysis with multiplets (coll. EOST)
- range survey for rift opening near the Psathopyrgos fault (collaboration with ENS)
- tomography from seismic noise correlations

Les participations

Partenaire	Nom	Prénom	Emploi actuel	Discipline	Personne. mois	Rôle/Responsabilité dans le projet 4 lignes max
Leader	Deschamps	Anne	DR2 CNRS	Seismology	8	Microseimicity study and upper crust tomography
Other members	Lebourg	Thomas	MCF UNS	Geology/Geophysics	5	Deformation quantification and analysis
	Delouis	Bertrand	MCF UNS	Seismology	1	Earthquakes caracterisation
	Stehly	Laurent	Ph adjoint	Seismology	2	upper crust tomography, temporal variation of crustal characteristics
	xxxx		stagiaires	Geology		Deformation, landslides, fault
	xxxx		stagiaires	Seismolgy		Ambient noise, tomography

03 – CRPG

The participants belong to the Geodynamics and Geochemistry groups (3 researchers). The geodynamics group has a long experience in mapping, analysis and 3D modelling of fault systems in the Corinth rift with the aim of reconstructing the detailed history rifting and fault activity. The group will contribute the production of detailed maps and analyses of the onland fault system in the target area, dating of exposed fault surfaces and marine terraces and the production of a 3D geometrical model of the fault system. This team will work in close collaboration with colleagues in Greece and the ING Rome.

04 – LGCA/LGIT Universite de Chambery

Led by C. Beck and A. Hubert-Ferrari (External Coll., 15 man.months) , the following group will focus on offshore paleoseismic data acquisition and their tectonic interpretation through analysis of sedimentary accumulations. The data acquisition tools are: high resolution seismic-reflexion imaging, coring, and laboratory analyses (dating and characterization of co-seismic layers or disturbances). Sub-contractant M. De Batist will manage the seismic reflexion surveys and subsequent data processing and interpretation. Sub-contractants S. Schmidt, JL Schneider, and M. Cremer (Univ. of Bordeaux) will respectively contribute to chronology (radiometric dating and estimation of sedimentations rates), sedimentary processes analyses, core X-ray picture analysis, and seismic reflexion interpretation. C. Beck will apply specific analyses (textural properties on cores, acoustic facies) for co-seismic assessment of sedimentary features. The whole group will contribute to the time and space distribution of co-seismic offsets along the selected faults sections, in order to discuss the probabilistic aspect at least for the last 15000 years, and may be a longer period for the major events. In LGCA, C. Campos, Doctorate student, began in October 2009, a detailed sedimentological study of the eastern part of the Gulf of Corinth (continuation of A. Van Welden’s Thesis) and of the Sea of Marmara, providing the long giant-piston cores retrieved during previous surveys.

Starting from April 2010, as L.G.C.A. and the Laboratoire de Géophysique Interne et Tectonophysique (L.G.I.T.) will be associated into a unique Research Unit, and C.Beck will be member of a team dedicated to fault behaviour study and modelling at all dimensional and temporal scales.

05 - ENS

The geological laboratory at ENS (Ecole Normale Supérieure) is one of the two research groups of the ENS-TAO department (Terre Atmosphère Océan). Our team is specialized in

the study of the Earth deformation at all ranges of timescale, from second (seismology) to hundreds of million years
(mantle rheology).

One of our research axis is devoted to the Earth dynamics. The team is one of the most active partners of the Corinth Rift Laboratory project (European project) in Greece. It is also involved in seimotectonic research in other areas around the Mediterranean: Algeria, Bulgaria, Italy, Turkey. It was involved in several recent national and international research projects with local partners in Central America "Active tectonics and kinematics of the Polochic-Motagua fault system in Central America"

The ENS team in this project, composed of three permanent CNRS researchers.
Hélène Lyon-Caen (DR2) and Pierre Briole (DR2), who have great experience in measuring and modeling surface deformation induced by seismic activity (seismology, GPS and Insar).
Julie Carlut (CR1), who will use her expertise in geomagnetism to characterize core samples for the paleoseismology. Beside the chronological aspect, Anisotropy of Magnetic Susceptibility (with control of magnetism carrier grains) will be used for textural characterization of specific co-seismic layers or disturbances (see below, Paragraph. 06 LGCA) .

06 – IRSN

http://www.irsn.org)

IRSN (Institute of Radioprotection and Nuclear Safety) is a public establishment of an industrial and commercial nature placed under the joint authority of the French Ministries of the Environment, Health, Industry, Research and Defence. IRSN employs about 1,600 people including engineers, researchers, physicians, agronomists, veterinary surgeons and technicians, skilled experts in nuclear safety and radiological protection and in the field of controlling sensitive nuclear materials. Its expertise and research studies serve to assess the nuclear and radiological risk serving public authorities.
Participation to projects in progress concerning this theme:
• ANR CATELL 2005 – Seismic simulation in complex source-site effect (SEISMULATORS) coordinated by BRGM
Main members of research team to this proposition

• Scotti, Oona (researcher in seismic hazard assessment): PhD in 1991 at Univ. of Stanford California. Joined IRSN in 1997. Develop and implement methodologies for the computation of seismic hazard for nuclear power plants.

IRSN's participation to the project is essentially three-fold: structuring the existing and new data into a logic-tree formulation. IRSN will contribute to the statistical analysis of the earthquake catalogue and to the association of earthquakes with know active faults.

5.2. QUALIFICATION DU COORDINATEUR DU PROJET / QUALIFICATION OF THE PROJECT COORDINATOR

Pascal Bernard, Phycien du Globe, IPGP

- Coordinator of several European projects in FP5 et FP6 focussed on the Corinth rift :
GAIA (10 partners), CORSEIS (8 partners, 660 KEuros), 3HAZ (18 partners, 1500 keuros)
- involvement in CRL scientific committee and the CRL team for in situ monitoring
- scientific collaboration (data analysis, field work) with the Greek partners of CRL since 1990 research (data analysis, field work) at CRL with more than half of the French partners since 1990, and all the Greek external collaborators.
- Responsible for tilt measurements in the North Chili IPOC international project.

Pascal Bernard has thus already coordinated several multidisciplinary research programs like SISCOR, involving tight interaction between seismology, geodesy, tectonics, and geophysics. His own expertise in strong ground motion simulation, space-time seismicity processes, and transient activity of faults, will allow him to contribute scientifically to some of the Tasks, and thus to better promote interaction between Tasks and between the many aspects of geosciences involved.

5.3. QUALIFICATION, ROLE ET IMPLICATION DES PARTICIPANTS / CONTRIBUTION AND QUALIFICATION OD EACH PROJECT PARTICPANT

Partner	Nom	Prénom	Emploi actuel	Discipline	Personne.mois	Rôle/Responsabilité dans le projet 4 lignes max

1. IPGP – coordinateur	BERNARD	Pascal	Physicien	Seismology	20	Coordination Transient deformation – seismicity
1. IPGP	FAVREAU	Pascal	MCF	Seismology	6	Rupture Dynamics - Asperities
1. IPGP	VILOTTE	Jean-Pierre	Physicien	Seismology	4	Rupture dynamics
1. IPGP	NERCESSIAN	Alex	Physicien Adjoint	Seismology	4	Seismicity- station telemetry
1. IPGP	BRUNET	Christophe	IR	Seismology	10	Borehole installation of seismoemter and tiltmeter
1. IPGP	EL MADANI	Essaoui	IR	Seismology	6	Telemetry/data base
1. IPGP	DUBLANCHET	Pierre	PhD	Seismology	30	Mechanics of asperities, microseismicity
1.IPGP	CANITANO	alexandre	PhD	Seismolgy	10	Strain analysis
1. IPGP	X	X	postdoc	Mechanics	12	Numerical simulation of 3D rupture dynamics
5. ENS	BRIOLE	Pierre	DR	Geodesy	9	Geodesy GPS – models and observation
5. ENS	LYON-CAEN	Hélène	DR	Seismology	18	Seismicity - modeling
5.ENS	DRAB	Laureen	PhD	Tectonics	3	Tectonics – Paleoseismicity
5.ENS	CARLUT	Julie	CR	Geomagnetism	1	Core Analysis
5. ENS	DUBERNET	Pierpaolo	I2	Computing	3	website
5.ENS	FINDLING	Nathaniel	TC	Tech. Asist.	3	Field work
5. ENS/subcontractant EOST	LAMBOTTE	Sophie	Phys.Adj.	Seismology	4	Microseismicity studies
5. ENS/sub contractant PARIS 6	ROLANDONE	Frédérique	MCF	Deformation	3	geodesy GPS, 3D non elastic modeling with Zset/Zebulon
5. ENS/sub contractant ONERA	GARAUD	Jean-Didier	Ch.	Num.. Modeling	2	Zset-Zebulon expertise
5. ENS	x		Post-doc	mechanics	18	3D non elastic modeling
5. ENS (on a different budget)	x		PhD	seismology	36	Microseismicity studies
5. ENS (on a diferent budget)	x		PhD	GPS	12	GPS data analysis and modeling
6. IRSN	SCOTTI	Oona	Ch.	Seismology	7	Seismicity – Probabilistic approach

6. IRSN	xxxx	xxxx	Thesis	Seismology	36	Integrating fault and seismicity in probabilistic earthquake hazard
2. GEOAZUR	DESCHAMPS	Anne	DR	Seismology	5	Seismicity – Structure
2 GEOAZUR	STEHLY	Laurent	CR	sismologie	2	Tomography noise correlation
2 GEOAZUR	LEBOURG	Thomas	CR	geophysique	6	Geodetic surveys
3. CRPG	FORD	Mary	prof	Tectonics	6	Long term tectonics, active faults
3. CRPG	CHARREAU	Julien	MdC	Tectonics	1.5	Long term tectonics, active faults
3. CRPG	BLARD	Pierre Henri	CR	Geochemistry	1.5	Dating of fault exposure surfaces using cosmogenic nucleides
3. CRPG	Ph D Student		PhD student	Tectonics modelling	12	tectonics active faults, 3D modelling
4. Université de Savoir/LGCA	BECK	Christian	Prof	Sedimentlogy	7,2	Sedimentological studies
4. LGCA/subcontractant Univ. De Bordeaux	SCHNEIDER	Jean-Luc	Prof	Sedimentlogy	10,2	Sedimentological studies
4. LGCA /subcontractant Univ. De Bordeaux	SCHMIDT	Sabine	CR1	Geochronolgy	5	Sediment dating
4. LGCA/subcontractant Univ. De Bordeaux	CREMER	Michel	CR	Sedimentlogy	2	Sedimentological studies
Foreign Collaborats and subcontractants to SISCOR						
Universite de Liège /LGCA	HUBERT-FERRARI	Aurélia	CR	Tectonics	15	Tectonics – Paleoseismicity
R.C.M.G. University Ghent/LGCA	DE BATIST	Marc	Prof	Sedimentology		High resolution seismic reflexion
Imperial College London Greek Academy of Science /ENS	AMBRASEYS	Nicholas	Prof	Historical seismology	1	Historical archives
INGV/ ENS	AVALLONE	Antonio	MCF	Geodesy	1	GPS measurements, processing and analysis
Harokopio University Department of Geography/CRPG	PALYVOS	Nikos	posdoc	Tectonics	2	Active Tectonics on the Psathopyrgos fault
Univ. Patras/ CRPG	STIROS	Stathis	Prof	Tectonics	2	Geodesy / historical seismicity
Helike Society / IPGP	KATSONOPOULOU	Dora	Prof	Archeology	2	Excavation on Lambiri fault

NOA /ENS	ELIAS	Panayotis	PhD	Geodesy	3	InSAR images
INGV /ENS	ALBINI	Paola	Senior Researche r	Historical Seismology	1	Research in archives Venise, Athènes and London f
Main collaborators to CRL with no budget from ANR						
Univ. Patras – Seismo Lab	SOKOS	Thimios	Prof	Seismology		CRL greek stations and data base
Univ Athens – Lab. Geophysicis	PAPADIMITRIOU	Panayotis	Prof	Seismology		CRL greek stations and data bases
Univ. Athens – Lab. Geophysics	VOULGARIS	Nikos	Prof	Seismology		ATHNET seismological data base
Univ. Patras	XXX	XXX	Eng.	seismology	3	Technical and field support for maintaining of stations.
OASP	MAKROPOULOS	Kostas	Prof	Civil Protection		Seismic hazard and preparedness in Greece; contact with local authorities
INGV	PANTOSTI	Daniela	DR	Tectonics		Active tectonics on the Psathopyrgos fault

6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDES / SCIENTIFIC JUSTIFICATION OF REQUESTED BUDGET

General considerations on the Budget :

The budget requested to ANR is quite high, being approximately double of the mean budget for ANR Blanc projects, due to the ambitious character of the project, as explained in 3.2. One shall note that:

- the contribution of ANR benefits to research teams in 6 main French Institutions, plus 3 associate institutions (Univ. Paris 6, EOST, Univ. Bordeaux).
- 21 researchers with permanent position in France are involved, with significant additional manpower of foreign research groups collaborating within SISCOR (see Table 5.3, in particular Université de Liège))

Globally, in the ANR requested contribution, we tried to keep the balance between salaries (Postdoc and Thesis), new equipment, and field work.

The budget of partners is in adequation to their contribution in permanent man power. Note also that the new equipment is considered as a contribution to the “site instrumenté” CRL, thus becoming a French, National equipment. Its maintaining during and after the project will be under the scientific responsibility of the CRL consortium, and under the technical responsibility of the owning partner.

Concerning the CRL equipment used by SISCOR, 5 new recorders have been provided to CRL in 2009 by ENS and IPGP, for upgrading the seismological array; this upgrade may hopefully be completed in 2010 thanks to the financial support requested to INSU by the CRL group, as a support for a “site instrumenté”.

Finally, the project benefits from the work of the Greek and Italian colleagues within CRL, and of their own equipment (see details in Table 5.3 and Figure 2 monitoring arrays), independently of SISCOR.

6.1. Partenaire 1 / partner 1 : IPGP

- *Équipement*

- 2 borehole tiltmeters for the monitoring of creep activity of the Pasthopyrgos fault and the detection of transients. (possibly the LILY applied geomechanics) – 26 Keuros
- 1 borehole seismometer for the monitoring of the micro-seismicity of the Psathopyrgos fault : 15 keuros
- 2 surface short period seismometers (WMD, EPF) 5 keuros
- 3 seismic recorders (3 comp) (WMD, EPF, SMD) 18 keuros
- solar pannels (seismic and titlmeter stations) 4 keuros
- 3 accelerometers (WMD, EPF, PYR) 7.5 keuros

total: 75.5 keuros

Note :

- the budget for the recorders (about 18 keuros) of the accelerometers will be taken from another source.
- 1 seismic recorder has been purchased by IPGP in dec. 2009 for contributing to the upgrading of CRL (see Annex).

- *Personnel*

- 12 months postdoc for the development of numerical codes for non coplanar, multifault 3D dynamic rupture: 49 keuros

- 2 months of CDD for coordination secretary: 5.2 keuros

total: 54.2 keuros

- *Prestation de service externe*

- construction 3 shelters (site WMS, EPF, SMD) - 6 keuros
- Drilling, casing , logging, cementing 150 m borehole in soft sediments (SMD) – for sismometer 35 keuros
- Drilling, casing , logging, cementing 100 m borehole in conglomerate (EPF) – for tiltmeter 23 keuros
- Archaeological investigation (D. Katsonopoulou, Helike Society): geophysical survey, excavations of ancient harbour 12 keuros

Total 76 keuros

- *Missions*

- 2 Drilling, Installation of tiltmeters and borehole seismometer, 4 weeks, 2 people : 8 keuros
- Project Meetings in France and Greece (coordination) 5 keuros
- contribution to conferences 3 keuros

Total 16 keuros

note: the budget for maintaining the stations will be taken on the resources provided by INSU for maintaining the CRL equipment (demande en cours d'evaluation)

- *Autres dépenses de fonctionnement*

- petit materiel pour les abris des nouveaux sites
2 keuros

- Batteries pour les 3 station sismologiques et les deux inclinometres. 4 keuros

- contribution to publication: 2 keuros

total : 8 keuros

total general : 227.7 keuros

frais de gestion 4%

total avec frais de gestion: 236.81 keuros

6.2. Partenaire 5 / partner 5: ENS

Équipement / Equipment

- 4 GPS receivers and installation :
  6K€ (receiver) + 4k€ (installation) 4x10= 40K€
- 2 seismological stations, seismometers and installation:
  11K€ (recorder and seismometer) + 4k€(installation) 2x15= 30K€

note:
- Three other GPS stations will be acquired and installed by the University of Patras
- 4 recorders 3 comp., belonging to ENS, will be provided for upgrading of the CRL seismic array.

Personnel / Staff

1 post-doc for the 3D non elastic modeling, 18 months 73.5 k€

The candidate should have some expertise in finite element modelling and mechanics. Expertise in geophysics is not required but would be greatly appreciated.

restation de service externe / Subcontracting

Expertise of J.D. Garaud from ONERA on the 3D code Z-set/Zebullon 10K€
Expertise of N. Ambraseys (Imperial College) on historical seismicity 5K€
External collaboration of P. Albini on historical archives before 1800 25K€

Missions / Missions

Field work for GPS surveying :
3 field work campaigns (one each year) are planned: 2 weeks, 6 persons with 15 GPS receivers, field expenses: 15K€ per campaign 45K€
Field work for seismological stations 8K€
Project meetings in France (for 4 persons) 8K€
Scientific meetings 5K€

Autres dépenses de fonctionnement / Other expenses

Publications	3K€
Contribution to the Laboratoire de Geologie equipement and fonctionnement :	10K€
TOTAL :	262.5K€
CNRS overheads (4%)	10.5K€
TOTAL with overheads	273K€

6.3. PARTENAIRE 6 / PARTNER 6 : IRSN

Personnel

36 months PhD thesis for the development of Probabilistic Earthquake occurrence models for . Title: "Seismic Cycle and seismic hazard for a network of active normal faults: the case of the Gulf of Corinth, "

The candidate should have obtained an M2 level degree, have good knowledge of statistical treatment of data; previous experiences in the analysis of seismological data is and or in the general field of seismic hazard assessment is preferred. A key quality of the candidate will be his/her willingness to work in a multipdisciplinary and multy-university environment.

Thèse 125580 keuros*

- ***Missions***

Field trip in 2 keuros
Coordination meeting with end-users in : 2 keuros
Conferences: 2 keuros

- ***Autres dépenses***

Publications: 4 keuros

Coût complet (€)	**384 029**
Coût éligible pour le calcul de l'aide : Assiette (€)	**141 003**
Taux d'aide demandé	50%
Aide demandée (€)	**70 502**

*Une demande de cofinancement de la thèse est en cours à l'IRSN

6.4. Partenaire 2 / partner 2 : GEOAZUR

Personnel / Staff

Il est prévu de faire travailler sur ce projet 3 Master 2 : 3x6x400 euros =7,20 k€

- analyse des données sismologiques de bruit de fond sismologique. Ce travaille comporte l'adaptation des logiciels disponibles actuellement à Géoazur aux données des capteurs sur CRLNET qui devraient permettre de caractériser la croûte supérieure.
- Modélisation des sismogrammes des séismes de magnitude supérieure à 2.5 : apport possible sur la détermination de la profondeur et de la magnitude.
- Mesure de la déformation autour de la faille de Psatopyrgos et analyse des données en essayant de séparer le signal gravitaire du signal tectonique.

TOTAL: 7.2 KEUROS

Missions / Missions

Missions sur le terrain pour installation et remesure du dispositif de quantification de la déformation, 8 x 1200 euros 9,60 k€
Missions pour collaboration avec les collègues de Strasbourg et Paris 1,60 k€
Missions de participation au projet 2,00 k€
Missions pour colloque et/ou congrès 3,00 k€
TOTAL: 16.2 KEUROS

Dépenses justifiées sur une procédure de facturation interne / Internal expenses

Frais de calcul 3,00 k€
Frais de stockage et sauvegarde de données 2,75 k€
TOTAL: 5,75 KEUROS

Autres dépenses de fonctionnement / Other expenses

Frais de terrain pour l'installation du réseau de mesure de déformation 14,00 k€
Frais de publication 3,00 k€

TOTAL : 17 KEUROS

Sous Total	**46,15 k€**
Overhead (4%)	**1,85 k€**
Total General	**48 k€**

6.5. Partenaire 3 / partner 3 : CRPG

Personnel

A PhD thesis financed by ICEEL (INSTITUT CARNOT ENERGIE ET ENVIRONNEMENT EN LORRAINE) will start in early 2010. The PhD student will devote part (one third) of his thesis to this project. Thesis project title: 3D Kinematic and Geometric Evolution of an active Normal Fault Network: Gulf of Corinth, Greece.

– ***Prestations de service externe (7 keuro)***

- Dating of fault surface exposures using Cl and He isotopes by the CEREGE — 2 keuro
- Biostratigraphic dating (palynology and foraminifera) of syn-rift sediments, University of Lüneberg, Germany — 5 keuro

– ***Missions (13.8 keuro)***

- Fieldwork for high resolution mapping and sampling of the onshore fault system, terraces, and syn rift stratigraphy (14 weeks , 4 people) — 10 keuro
- Conferences, meetings in France and kick-off and end-user meetings for 4 people — 3.8 keuro

– ***Autres dépenses de fonctionnement (8 keuro)***

- Publication costs — 1 keuro
- Consumables for isotope laboratory CRPG (He, Be dating) — 2 keuro
- Field expenses of Dr. Nikolos Palyvos and Dr.Marco Mancini — 5 keuro

6.6. PARTENAIRE 4 / PARTNER 4 : LGCA

Équipement / Equipment

No equipment requested

Personnel / Staff

Master student (2nd year) funding in LGCA (3 stays)…2400 €x3=**7200€**

SUB-TOTAL…7 200 €

Prestation de service externe / Subcontracting

- Multibeam bathymetry and high resolution seismic reflection acquisition and processing :
  - freight (shipping of material from RCM Ghent Belgium…**5000 €**
  - Data storage and processing…**1500 €**

  Subcontractant : Renard Centre of Marine Geology, Seismostratigraphy Unit, University of Ghent (Dir. M. De Batist)
- 210 Pb and 137 Cs measurements- (S. Schmidt) University of Bordeaux:…**5000 €**
- X radiography Scoopix, XRF :geochemical profiles; Uniesity of Bordeaux….**5000 €**
- Microscopy, magnetism: secular variation and paleo-intensity, Paris ENS, IPGP, MNHN…**1000 €**
- Mineralogy, stable isotopes, organic matter profiles: University of Liège…**2500 €**

SUB-TOTAL…20 000 €

Missions / Missions

Travel and local expanses (400 euros travel ticket + 80 euros/day)-22 days-4 people for seismic survey
……………………………………………..**8640 €**
Travelling between laboratory of students and samples shipping…**2500 €**
Travel and local expanses (400 euros travel ticket + 80 euros/day)-9 days-4 people for coring
…………………………………………………**4480 €**
Coring consumable (tubes, caps, etc.)…………………………………..**1000 €**

Working meetings (x 3) of T2-1 task group in Paris (**Prestations de service externe (7 keuro)**

- Dating of fault surface exposures using Cl and He isotopes by the CEREGE 2 keuro
- Biostratigraphic dating (palynology and foraminifera) of syn-rift sediments, University of Lüneberg, Germany 5 keuro

– ***Missions (13.8 keuro)***

- Fieldwork for high resolution mapping and sampling of the onshore fault system, terraces, and syn rift stratigraphy (14 weeks , 4 people) 10 keuro
- Conferences, meetings in France and kick-off and end-user meetings for 4 people 3.8 keuro

– ***Autres dépenses de fonctionnement (8 keuro)***

- Publication costs
1 keuro

- Consumables for isotope laboratory CRPG (He, Be dating)
2 keuro

- Field expenses of Dr. Nikolos Palyvos and Dr.Marco Mancini
5 keuro

5 participants)…**2850 €**

SUB-TOTAL…19 470 €

Dépenses justifiées sur une procédure de facturation interne / Internal expenses

Laser granulometric and MS analyses in LGCA…4500 €

SUB-TOTAL…4 500 €

Autres dépenses de fonctionnement / Other expenses

Boat rental (1500 euros per day)-20 days…30000 €
Van rental (150 euros per day)-22 days…3300 €
Shipping of coring device; conditioning and shipping of cores …5000 €

SUB-TOTAL…38 300 €

TOTAL Partner 6 :…89 470 €

note: the collaborator A. Hubert-Ferrari (Univ. Liege) will submit a project in Belgium for aditional datation work.

7. ANNEXES

7.1. REFERENCES BIBLIOGRAPHIQUES / REFERENCES

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Kohrs-Sansorny, C., **F. Courboulex, M. and A. Deschamps.** (2006). Ground motion simulation of two moderate size earthquakes in the Grenoble area using summation of small earthquakes. Third International Symposium on the Effects of Surface Geology on Seismic Motion, volume II.

Kontoes, C., P. Elias, O. Sykioti, **P. Briole,** D. Remy, M. Sachpazi, G. Veis, and I. Kotsis (2000), Displacement field and fault model for the September 7, 1999 Athens earthquake inferred from ERS2 satellite radar interferometry. *Geophys. Res. Lett.*, v. 27, p. 3989-3992.

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Lyon-Caen, H., P. Papadimitriou, **A. Deschamps,** **P. Bernard,** K. Makropoulos, F. Pacchiani, G. Patau, First results of CRLN seismic array in the western Corinth rift: evidence for old fault reactivation*, C.R. Geoscience 336,* 343-352, 2004.

Malartre, F. **Ford, M.** and Williams, E.A. **2004.** Preliminary biostratigraphy and 3D lithostratigraphy of the Vouraikos fan delta: Implications for the evolution of the Gulf of Corinth, Greece, *C.R. Géosciences*, 336, 269-280.

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Rigo, A., **H. Lyon-Caen,** R. Armijo, **A. Deschamps**, D. Hatzfeld, K. Makropoulos, P. Papadimitriou, I Kassaras, A microseismic study in the western part of the Gulf of Corinth (Greece): implications for large scale normal faulting mechanisms, Geophys. J. Int., 1996, 126, pp. 663-688

Rohais, S. , **Ford, M.,** Eschard, R., Guillocheau, F. & Granjeon, D.(submitted). Control of the source-to-sink distance on stratigraphic architecture : insights from 3D numerical modelling of the Gilbert-type fan delta of the Corinth rift (Greece). Basin Research

Rohais, S., Guillocheau, F., Eschard, R., **Ford, M.** and Moretti, I., 2007. Stratigraphic architecture of the Plio-Pleistocene infill of the Corinth rift : implications for its structural evolution. *Tectonophysics,* doi: 10.1016/j.tecto.2006.11.006

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breccia units of the Las Palmas Detritic Formation (Mio-Pliocene, Gran Canaria, Eastern Atlantic, Spain), Journal of Volcanology and Geothermal Research, 138, 295-323.

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Stehly, L., Campillo, M. Shapiro, N.M., 2007. Travel time measurements from noise correlation:
stability and detection of instrumental error, Geophys. J. Int. , 171 , 223–230

Stehly, L., B. Fry, M. Campillo, N. M. Shapiro, J. Guilbert, L. Boschi, D. Giardini, 2009. Tomography of the Alpine region from observations of seismic ambient noise, Geophys. J. Int. 178, 338-350.

Volant P., Levret A., D. Carbon, **O. Scotti**, D. Combescure, T. Verdel, A . Piant, P. Laurent, An archaeo-seismological study of the Nîmes Roman aqueduct, France: indirect evidence for an M> 6 seismic event? 49 – 1 pag 53 – 77, 2009

Widdows J., Blauw A., Heip C.H.R., Herman P.M.J., Lucas C.H., Middelburg , J.J., Schmidt S., Brinsley M.D., Twisk F., Verbeek H. (2004). Role of physical and biological processes in sediment dynamics. Marine Ecology Progress Series 274, 41-56.

7.2. BIOGRAPHIES / CV, RESUME

Pascal Bernard

Born 1958

Seismologist, Physicien du Globe, Equipe de Sismologie, Institut de Physique du Globe de Paris, IPGP, France

bernard@ipgp.jussieu.fr

Education :

1983 PhD Thesis - Thèse de 3ème Cycle, Univ. Paris 6. ; 1 987 Doctorat d'Etat, Univ. Paris 6.

Research : seismogenesis

- Measure and modeling of strong ground motion
- Observation and modeling of seismic source through a multidisciplinary approach
- Research on crustal transients and on precursory phenomen
- Development of geophysical observatories in Greece and Chile

Main Scientific and Administrative responsabities

Advisor for 15 PhD thesis; - Coordinator for 4 European projects on seismogenesis and seismic hazard; - Deputy director of IPGP 1999-2004; - Director of the seismogenesis group 1994-2005; member of Section 18 of CNRS – 2004-2008; member of CSS1 at IRD since 2008.

Selected recent publications in international journal with peer review:

Bernard, P., F. Boudin, S. Sacks, A. Linde, et al., Continuous strain and tilt monitoring on the Trizonia island, Rift of Corinth, Greece, *C.R. Geoscience 336,* 313-324, 2004.

Bernard, P., and D. Baumont, Shear *Mach* wave characterization for kinematic fault rupture models with constant supershear rupture velocity, *Geophys. J. Int. 162,* 431-447, 2005.

Bernard, P, H. Lyon-Caen, P. Briole, A. Deschamps, F. Boudin, et al., Seismicity, Deformation and seismic hazard in the western rift of Corinth : New insights from the Corinth Rift Laboratory (CRL), *Tectonophy. 426,* 7-30, doi:10.1016/j.tecto.2006.02.012, 2006.

Peyrat, S., J. Campos, J.-B. Dechaballier, A. Perez, S. Bonvalot, M.-P. Bouin, D. Legrand, A. Nercessian, O. Charade, G. Patau, E. Clévédé, **P. Bernard,** and J.-P. Vilotte, Source parameters of the Mw=7.7 Tarapaca intermediate-depth earthquake (June 13, 2005, Northern Chile) constrained from seismological and geodetic observations: A slab-pull event with a horizontal fault plane, *Geophys. Res. Lett.,* 33, L22308, doi:10.1029/2006GL027710, 2006

Bourouis, S., and **P. Bernard,** Evidence for coupled seismic and aseismic fault slip during water injection in the geothermal site of Soultz (France), and implications for seismogenic transients, Geophys J Int, 169, 723-

732, doi 10.1111/j.1365-246X.2006.03325.x, 2007.

Ruiz, J., D. Baumont, **P. Bernard,** and C. Berge, A new approach in the kinematic k-2 source model for generating physical slip velocity functions, *Geophys. J. Int.,* doi: 10.1111/j.1365-246X.2007.03503.x2007, 2007.

Boudin, F., **P. Bernard**, L. Longuevergne, N. Florsch, C. Larmat, C. Courteille, P-A. Blum, A silica long base tiltmeter with high stability and resolution. Rev. of Sci. Inst., 79, 034502 , 2008.

Mercerat, E.D.M., L.D. Riad, L Lebeau, and **P. Bernard,** Induced seismicity monitoring of an underground salt cavern prone to collapse, Pure App. Geophys. , DOI 10.1007/s00024-009-0008-1, 2009.

since 1985, more than 50 publication in international journals with peer review

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Current position	Directeur de Recherche CNRS
1990.2004	Chargé de Recherche CNRS
2000	Habilitation à Diriger des Recherches, Université Paris 7
1990	PhD University Paris 6 (« Mesure et Modélisation de Zones sismiques et de volcans »)
1983	Agrégation de Physique

Background and experiences: P. Briole, senior CNRS researcher, is expert in geodesy and remote sensing applied to volcanoes and seismic zones. He has been measuring and modelling since twenty years the ground deformation of several volcanoes in the Italy (Etna, Campi Flegrei, Vulcano), France (Piton de la Fournaise), Greece (Nisyros), Japan (Sakurajima, Myakejima), Portugal (Sao Miguel island). He has been also involved in the study of seismic areas in Greece (Gulf of Corinth), Chile (Atacama), Djibouti (Asal Rift), Algeria (Algiers region). He has been involved in fast post-seismic response, involving both field GPS campaigns and InSAR studies, after the 1992 earthquake of Galaxidi (Greece) the 1995 earthquakes of Grevena and Aigion (Greece), the 1995 earthquake of Antofagasta (Chile), the 1997 earthquakes of Umbria (Italy), the 1999 earthquake of Athens (Greece), the 2003 earthquake of Boumerdes (Algeria), the 2003 earthquake of Bam (Iran), the 2005 earthquake of Mushafarabad (Pakistan). He has been exchanging information with the PI of Charter activation, and quickly providing information and pre-existing knowledge, after several volcanic and seismic events: Nyiragongo 2002, Stromboli 2003, Boumerdes 2003, Bam 2003, Sumatra 2004, Pakistan 2005, China 2008. P Briole has been involved in several EU and ESA project concerning the monitoring on volcanoes in the last decade (TEKVOLC, MADVIEWS, EMPEDOCLE, ROBOVOLC, EMEWS, see http://briole.iterre.fr/spip/Projets.html). In particular he has been the leader of the project EMEWS aimed to the harmonisation at EU level of the mobile systems to be deployed on volcanoes during crisis (European Mobile Early Warning System, http://briole.iterre.fr/spip/Projets.html).

Publications in the last 5 years *(about 50 publications since 1990): see* http://www.geologie.ens.fr/~briole*)*

Mahsas A., K Lammali, K Yelles, E Calais, AM Freed, P Briole, Shallow afterslip following the 2003 May 21, M-w=6.9 Boumerdes earthquake, Algeria. *Geophys. J. Int.*, v. 172, p. 155-166, 2008.

Peyret, M., J. Chery, Y. Djamour, A. Avallone, F. Sarti, P. Briole, and M. Sarpoulaki, The source motion of 2003 Bam (Iran) earthquake constrained by satellite and ground-based geodetic data. *Geophys. J. Int.*, v. 169, p. 849-865, 2007

Bernard P., H. Lyon-Caen, P. Briole, A. Deschamps, K. Pitilakis, M. Manakou, F. Boudin, C. Berge, K. Makropoulos, D. Diagourtas, P. Papadimitriou, F. Lemeille, G. Patau, H. Billiris, H. Castarede, O. Charade, A. Nercessian, A. Avallone, J. Zahradnik, S. Sack, A. Linde, F. Pacchiani, Seismicity, deformation and seismic hazard in the western rift of Corinth: new insights from the Corinth Rift Laboratory (CRL), Tectonophysics, 2006.

Trota, A., N. Houlie, P. Briole, J. L. Gaspar, F. Sigmundsson, and K. L. Feigl, Deformation studies at Furnas and Sete Cidades Volcanoes (Sao Miguel Island, Azores). Velocities and further investigations. *Geophys. J. Int.*, v. 166, p. 952-956.

Houlie, N., P. Briole, A. Bonforte, and G. Puglisi, Large scale ground deformation of Etna observed by GPS between 1994 and 2001. *Geophys. Res. Lett.*, v. 33, 2006.

Anne Deschamps
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Current position	Directeur de Recherche CNRS at Géoazur.
1991-1992	Directeur de Recherche at Institut de Physique du Globe, Paris
1978-1991	Chargé de Recherche at Institut de Physique du Globe, Paris
1974-1978	Assistant professor at ENS, Paris
Degrees :	
1986	Doctorat d'état at University Pierre et Marie Curie, Paris VI
1974	Agrégation in Sciences Physics

RESEARCH ACTIVITY:
Seismic sources studies larges and small events, aftershocks distribution.
Microseimicity as information of deformation process.
Crustal and lithospheric tomography
Seismological observation (on land and on sea floor)

Publications in the last 5 years
Godano M., Deschamps A., Regnier M., Bardainne T. et Gaucher E., 2009. Determination of focal mechanisms from few sensors by a non linear inversion of direct waves amplitudes: method and applicative tests on synthetic and real data",Bull. Seism.Soc. Am., 99, 2243-2264.
Albaric J., Perrot J., Déverchère J., Deschamps A., Gall B.L., Ferdinand R.W., Petit C., Tiberi C., Sue C. et Songo M., 2009. Contrasted seismogenic and rheological behaviours from shallow and deep earthquake sequences in the North Tanzanian divegence, East Africa, Journal of African Earth Sciences.
Calais E., N. d'Oreye, J. Albaric, A. Deschamps, D. Delvaux, J. Déverchère, C. Ebinger, R. W. Ferdinand, F. Kervyn, A. S. Macheyeki, A. Oyen, J. Perrot, E. Saria, B. Smets, D. S. Stamps& C. Wauthier, Aseismic strain accommodation by slow slip and dyking in a youthful continental rift, East Africa, 2008, Nature, 456, 783-787, doi:10.1038/nature07478.
Petit, C., C. Tiberi, A. Deschamps, and J. Déverchère, Teleseismic traveltimes, topography and the lithospheric structure across central Mongolia, *Geophys. Res. Lett*., 2008, 35, L11301, doi:10.1029/2008GL033993
Wyss, M., F. Pacchiani, A. Deschamps, and G. Patau, Mean magnitude variations of earthquakes as a function of depth: Different crustal stress distribution depending on tectonic setting, *Geophys. Res. Lett.*, 2008, 35, L01307, doi:10.1029/2007GL031057.

Pascal Favreau

né le 02/10/1972 (37 ans)

Current position

Depuis Septembre 2002: Maître de Conférences à l'Institut de Physique du Globe de Paris.

Background and experiences:

2000-2002 : Post-doc à l'Université de Californie à Santa Barbara

1997-2000 : Doctorat à l'Université Joseph Fourier (Initiation et propagation de la rupture sismique: instabilité de frottement en élastodynamique.)

1996-1997: Service National

1996 : DEA de Géophysique à l'Université Joseph Fourier

1992-1995 : élève à l'Ecole Normale Supérieure de Cachan (Génie Civil)

Nombre total de publications dans les revues internationales et actes de congrés à comité de lecture: 10 (depuis 1999).

Publications in the last 5 years

Cinq publications les plus significatives des cinq dernières années :

Favreau, P. and R.J. Archuleta (2003). Direct seismic energy modeling and application to the 1979 Imperial Valley earthquake Geophys. Res. Lett. 30, 2002GL15968

Dunham, E.M., P. Favreau and J. Carlson (2003). A supershear transition mechanisms for cracks. Science, 2999,11571159

Favreau, P. and S. Wolf (2007). Theoretical and numerical stress analysis at edges of interacting faults. Application to fault propagation modeling. Accepted to Geophys. J. Int.

Peyrat, S. and Favreau P. (2008). Kinematic and spontaneous rupture models of the 2005 Tarapaca intermediate depth earthquake, in revision in Geophysical Journal International.

S. Wolf, P. Favreau and I.R. Ionescu (2008). Hybrid unstructured FEM - FDM modeling of seismic wave propagation. Application to dynamic faulting, Submitted to Journal of Geophysical Research.

Mary Ford

Current position

Professeur universitaire en géologie structurale et tectonique, Ecole Nationale Supérieure de Géologie, INPL, Nancy Université (Laboratoire de Recherche : CRPG)

Age: 49

Background and experiences:

Doctorat, 1985 National University of Ireland, University College Cork. Titre: Structural studies along a transect through the Variscides of west County Cork, Ireland.

1985-1986 : Stage post-doctoral à l'Université de Liverpool, Grande Bretagne.

1986-1990 : Maître de conférence, Université de Plymouth , UK,

1990-1998: Chercheur, Geologisches Institut, ETH-Zurich, Suisse

1998- actuel : Professeur, Nancy Université, Ecole Nationale Supérieure de Géologie

1999 : Habilitation, ETH, Zurich, Suisse "Foreland basin systems: an Alpine Perspective".

Profil:

Géologie structurale, tectonique des bassins, interaction sédimentation -tectonique dans les bassins d'avant-pays et dans les rifts

Publications in the last 5 years

39 Publications dans les revues internationales

Backert, N. , Ford, M. and Malartre, F. (2009) Architecture and sedimentology of the Kerinitis Gilbert-type fan delta, Corinth Rift, Greece, *Sedimentology*, doi: 10.1111/j.1365-3091.2009.01105.x

Ford, M., Le Carlier de Velsud, C., Bourgeois, O. & Diraison, M., 2007. Interaction of fault propagation folds and major normal faults: evolution of the SW Rhine Graben, *Journal of Structural Geology, 29*, 1811-1830.

Ford, M., Williams, E.A., Malartre, F. and Popescu, S.M., 2007. Stratigraphic architecture, sedimentology and structure of the Vouraikos Gilbert-type delta, Gulf of Corinth, Greece. 2007 *Special Publication of the International Association of Sedimentologists, No. 38,* eds G.J. Nichols, E.A. Williams, C. Paola,.49-90.

Bourgeois, O., Ford, M., Diraison, M., Pik, R., Gerbault, M., Le Carlier de Veslud C. Ruby, N. and Bonnet, S. 2007. Separation of rifting and lithospheric folding signatures in the NW alpine foreland. *J.P. Brun and D. Bernoulli (eds), International Journal of Earth Sciences,* DOI : 10.1007/s00531-007-0202-2

Rohais, S., Guillocheau, F., Eschard, R., Ford, M. and Moretti, I., 2007. Stratigraphic architecture of the Plio-Pleistocene infill of the Corinth rif: implications for its structural evolution. *Tectonophysics,* doi: 10.1016/j.tecto.2006.11.006

Ford, M., Duchene, S., Vanderhaeghe, O. and Gasquet, D. 2006. Coupling of external and internal orogenic processes in the SE Alps during frontal to oblique collision, *Journal of the Geological Society of London*, July 2006.

Prix, distinctions

2000 : '*European Distinguished Lecturer*' pour l'AAPG (American Association of Petroleum Geologists).

Aurelia HUBERT-FERRARI

CR1, Laboratoire de Géologie de l'Ecole Normale Supérieure, UMR 8538
Age: 37

Background and Experiences

Doctorate, 1998 Institut de Physique du Globe de Paris- Université Paris VII. Subject: Seismotectonics of the North Anatolian Fault (Estimation of its Quaternary slip rate and of its total displacement, and modeling of its propagation and of stress couplingbetween earthquakes);

1998-2001 : Post-doctoral Research Associate, Princeton U., USA.
2001-2005 : Postdoctoral fellow and lecturer, Institute of Geology, U. de Neuchatel, Switzerland.
2005-2009: Leader of a Marie Curie Excellence Team at the Royal Observatory of Belgium funded by the European Commission.

The project funded for research expenses and salaries for myself and three team members (one post-doc and two PhD students).This project entitled: "Seismic cycle", was seeking to obtain a most extensive chronology of past seismic events along both the North and the East Anatolian Faults in Turkey for a better understanding of the irregularities in the seismic cycle. For that purpose, we use a diverse array of complementary techniques,involving trenching across the fault combined with subsurface geophysics, dating of displacedgeomorphic features and coring of lake sediments along the fault trace. This research is having some unexpected developments, more specifically in the field of paleoseismology using lake sediments.

2008-present : CNRS Researcher (CR 1) at the Laboratoire de Géologie de l'Ecole Normale Supérieure de Paris.

Significant publications in the last 5 years

Fraser J., Pigati J.S., A. Hubert-Ferrari, K. Vanneste, U. Avsar, S. Altinok., 2009, A 3000-year record of ground rupturing earthquakes along the central North Anatolian Fault near Lake Ladik, Turkey, accepté dans Bulletin of Seismological Society of America.

Boës X., S.B. Moran, J. King, N. Cagatay, A, Hubert-Ferrari, 2009, Large earthquakes Cycles in Lake Sediments along the North Anatolian Fault, Turkey, accepté dans Journal of Paleolimnology

Hubert-Ferrari A., J. Van Der Woerd, G. King, R. Armijo, I. Villa, 2009, Long-term evolution of the North Anatolian fault (Turkey), sous pressedans in Special Publication of the Geological Society of London :Geodynamics of Collision and Collapse at the Africa-Arabia-EurasiaSubduction Zone, Editor R. Govers.

Hubert-Ferrari A., J. Suppe et R. Gonzalez-Mieres, 2007, Mechanisms ofactive folding of the landscape (Southern Tianshan, China), Journal ofGeophysical Research 112, doi: 10.1029/2006JB004362.

Hubert-Ferrari A., J. Suppe, J. Van Der Woerd, X. Wang et H. Lu, 2005,Irregular earthquake cycle along the southern Tianshan front, China (Aksuarea), Journal of Geophysical Research 110, doi:10.1029/2003JB002603.

Sophie Lambotte

Physicien-adjoint, Ecole et Observatoire des Sciences de la Terre (EOST), Strasbourg, France.
Sophie.Lambotte@eost.u-strasbg.fr
Age: 29

Education:
2007 PhD thesis (Strasbourg University)
2007-2009 Postdoctoral fellow, Ecole Normale Supérieure, Paris

Research interests:
Low frequency seismology and gravimetry, free oscillations, Earth tides, local effects (earth-atmosphere coupling), seismic sources, microseismicity (multiplets, relocation, …).

Publication in the last 5 years:
De Linage C., L. Rivera, J. Hinderer, J.-P. Boy, Y. Rogister, **S. Lambotte**, R. Biancale, 2009, Separation of coseismic and postseismic gravity changes for the Sumatra-Andaman earthquake from the 4.6yr GRACE observations and modelling of the coseismic change by normal-modes summation, *Geophys. J. Int.*, doi:101111/j.1365-246X.2008.04025.x.

Lambotte S., L. Rivera, and J. Hinderer, 2007, Constraining the overall kinematics of the 2004 Sumatra and the 2005 Nias earthquakes using the Earth's gravest free oscillations, *Bull. Seismol. Soc. Am.*, 97, S128-S138, doi:10.1785/0120050621.

Lambotte S., L. Rivera, and J. Hinderer, 2006, Rupture length and duration of the 2004 Aceh-Sumatra earthquake from the Earth's gravest free oscillations, *Geophys. Res. Lett.*, 33, L023307, doi:10.1029/2005GL024090.

Lambotte S., L. Rivera, J. Hinderer, 2006, Vertical and horizontal seismometric observations of tides, *J. Geodynamics*, 41, 39-58.

Dessa, J.-X., J. Virieux, **S. Lambotte**, 2005, Infrasound modeling in a spherical heterogeneous atmosphere, *Geophys. Res. Lett.*, 32, L12808, doi:101029/2005L022867.

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Current position Assistant Professor at UNS (University of Nice Sophia Antipolis since 2001
2008: Accreditation to Supervise Research (University of Nice, France)
2000: Ph.D., Geology, University of Bordeaux I (France)
1997: B.Sc, Engineering Geology, Ecole Centrale of Paris
1996: Master of applied geology, Bordeaux I University

TEACHING EXPERIENCES:
Teaching Risk and landsliding processes, Geophysical survey and Soil mechanics and rheology at the University of Nice (France)
Supervisor of 6 PhD students.

RESEARCH ACTIVITY:
Landslides (triggering, process, evolution).Geophysical research and experimentation in 3D and 4D (3 landslides laboratory monitored), Granular behaviour (mechanical and physical research, image analysis), and weathering characterisation and processes).

Publications in the last 5 years

Lebourg T., S. El Bedoui Y. Guglielmi & M. Hernandez. 2009. Control of slope deformations in high seismic area: results from Gulf of Corinth observatory site (Greece). Engineering Geology, N) 108, pp.295-303.

Jomard H., Lebourg T, Guglielmi Y and Tric E., 2009. Electrical imaging of the sliding geometry and fluids associated to a deep seated landslide, example of the la Clapiere landslide (france). Earth Surface Processes and Landforms.

S. El Bedoui, Y. Guglielmi, T. Lebourg and J.L. Pérez. 2008. Estimation of deep seated progressive failure propagation rates in a fractured rock slope over a 10 kyears period: results from the « La Clapière » slope (Southeastern French Alps). Geomorphology, volume 105, issues 3-4, pp 232-238.

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Hélène Lyon-Caen

born 11/03/1956, 2 children
Directrice de Recherche, CNRS, Laboratoire de Géologie, Ecole Normale Supérieure
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Education :
1976 : Ecole Normale Supérieure, Sèvres, mathématiques
1978 : DEA Géophysique interne
1980 : Thèse de 3ème cycle, Université Paris 7, sismologie
1985 : PhD thesis, Massachussets Institute of Technology, geophysics

Research interests:
seismotectonics, seismic sources, relationship active faults-seismicity-crustal deformation, seismic cycle, fault interactions

Responsabilities:

- Deputy director of the Laboratoire de Géologie, ENS since 2006-
- Head of the "Dynamique de la Terre" group at Laboratoire de Géologie, ENS: 2003-2006
- Scientific responsabilities in EC projects related to Corinth Rift (EPOCH, SeisfaultGreece, Aegis, Corseis, 3HAZ)

Awards: bronze medal of CNRS: 1993

Advisor of 6 Ph.D. thesis, 42 publications in international journals

5 Publications over the last 5 years:

Zahradnik J., J. Jansky, E. Sokos, A. Serpetsidaki, **H. Lyon-Caen** and P. Papadimitriou, Modeling the Ml=4.7 mainshock of the February-July 2001 earthquake sequence in Aegion, Greece, *J. of Seism*., 8, 247-257, 2004

Lyon-Caen H., P. Papadimitriou, A. Deschamps, P. Bernard, K. Makropoulos, F. Pacchiani, First results of CRLN seismic array in the western Corinth rift: evidence for old fault reactivation, *C. R. Geoscience*, 336, 343-351, 2004

Latorre D., J. Virieux, T. Monfret, V. Monteiller, T. Vanorio, J.L. Got and **H. Lyon-Caen**, A new seismic tomography of Aigion area (Gulf of Corinth-Greece) from the 1991 dataset, *Geophys. J. Int.*, 159, 1013-1031, 2004

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Activities :

Seismic sedimentary records ; volcanoclastic sedimentation ; natural hazards. Study areas : Gulf o Gascogne, Marmara Sea, Petites Antilles, Canary Islands. Co-ordinator of the 1st year masters course (ENVOLH).

Expertise / Responsabilities : Event sedimentology

Significant publications in the last 5 years :

Bourget J., Zaragosi S., Garlan T., Gabelotaud I., Guyomard P., Dennielou B., Ellouz-Zimmermann N., Schneider J.L., and the FanIndien 2006 survey crew (2008) Discovery of a giant deep-sea valley in the Indian Ocean, off eastern Africa: The Tanzania channel, Marine Geology, 255, 179-185.

Beck C., Mercier de Lepinay B., Schneider J.L., Cremer M., Cagatay N., Wendenbaum E., Boutareaud S., Menot G., Schmidt S., Weber O., Eris K., Armijo R., Meyer B., Pondard N., Gutscher M.A., Turon J.L., Labeyrie L., Cortijo E., Gallet Y., Bouquerel H., Gorur N., Gervais A., Castera M.H., Londeix L., de Resseguier A., Jaouen A. (2007) Late Quaternary co-seismic sedimentation in the Sea of Marmara's deep basins, Sedimentary Geology, 199, 65-89.

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Pollet N., Schneider J.L. (2004) Dynamic disintegration protestes accompanying transport of the Holocene Flims sturzstrom (Swiss Alps), Earth and Planetary Science Letters, 221, 433-448.

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Education
1983 Thèse de Troisième cycle, Géophysique, Université de Montpellier
1989 Doctorat d'état, Géophysique, Université de Montpellier
Profession
Position Physicien des Observatoires, première Classe
Institute Institut de Physique du Globe de Paris (CNRS UMR 7580)
Research Topics
Mechanic and Dynamic earthquake modelling; Wave propagation in complex media; Granular physics and Parallel computing
Scientific Responsability
Director of the Parallel and Data Centre (IPGP)
Director of the seismology laboratory (IPGP-CNRS) 2003-2007
Director of the National Parallel Computing Centre in Earth Sciences 1994 – 1997
International experience
University College of Swansea, Civil Engineering Department, Royal Society fellowship (1982-1984)
Arizona State University, Department of Geology, visiting fellow, 1984 (4 mois)
Brown University, Deparment of Engineering, NATO fellowship, 1990-1991 (1 an)
Tokyo University, Earthquake Research Institute, invited professor, 2007 (4 mois)
University California Berkeley, Department of Earth and Panetary Sciences, Miller research Professor, 2007-2008 (1 an)

Publications Auteur et co-auteur de 80 publications internationales

Vilotte J.-P., Festa G. And Ampuero J.-P. (2009), « Earthquakes dynamic simulation using non-smooth Spectral Element method », Bull. Sosc. Seism. Am., submitted.

G. Festa and Vilotte J.P. (2009), Dynamic rupture propagation and radiation along kinked faults: in-plane numerical simulation using non smooth spectral element method, Geophys. J. Int, in press.

Chaljub E., Komatitsch D., Vilotte, J.-P., Capdeville, Y., Valette, B. and Festa G. (2007), "Spectral Element Analysis in Seismology, in Advances in Wave Propagation in Heterogeneous Media », edited by R-S Wu and Maupin V., *"Advances in Geophysics"* series, Elsevier, vol. 48, 365-419.

Mangeney A., Bouchut F., Thomas N., Vilotte J.-P. And Bristeau M.O. (2007), "Numerical modelling of chanelling granular flows and of the levées channel morphology of their deposits", J. Geophys. Res., 112, 02017,doi:10.1029/2006JF000469.

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J.-P. Ampuero, Vilotte J.-P. and Sanchez-Sesma F.J. (2002), Nucleation of rupture under slip-dependent friction law: simple models of fault zone, J. Geophys. Res., 107 B12, doi:10.1029/2001JB00452.

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7.3. Implication des personnes dans d'autres contrats / involvement of project participants to other grants, contracts, etc …

Part.	Nom de la personne participant au projet	Personne. mois	Intitulé de l'appel à projets Source de financement Montant attribué	Titre du projet	Nom du coordinateur	Date début & Date fin
1	Bernard	3	ANR CATELL	ASEISMIC	D. MARSAN	2008-2011
1	Bernard	3	ANR RISNAT	LINES	J. CHERY	2009-2011
5	Briole	2	ANR-RISK	MAREMOTI	H. HEBERT	2009-2011
5	Briole	1	ANR-Masses de données et connaissances	EFIDIR	E. TROUVE	2008-2010
5	Briole	0.5	FP7	SAFER	INFOTERRA	2009-2010
1	Favreau	10.8	ANR Jeunes Chercheurs.	ASEISMIC	David Marsan	2008-2010
1	Favreau	8	ANR Risknat	PreTI-SIZE	Satish Singh	2009-2011
3	Ford		APST-INSU 2009	rifting continental précoce	M. FORD	2009-2011
6	Scotti	1	ANR RISK	ADN	JM Nocquet	2007-2010
6	Scotti	1	ANR RISK	ADN	JM Nocquet	2007-2010