The Corinth Rift Laboratory or an *in situ* Investigation on Interactions between Fluids and Active Faults

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doi:10.2204/iodp.sd.s01.20.2007

Objectives

Earthquakes result from the sudden acceleration of a preliminary long-term slow deformation process. The objective of the Corinth Rift Laboratory (CRL) is to investigate *in situ* this quasistatic deformation process and mechanisms leading to a sudden catastrophic acceleration. Of particular interest is the characterization of the structure of the deforming zones and of the progressive localization of deformation. Special attention is given to the role of fluids but also on the influence of faults on regional fluid flow.

Corinth Rift Laboratory

The Gulf of Corinth, in western Greece, is one of the most seismically active regions in Europe. It is possibly the fastest continental rift in the world and provides an ideal site for an *in situ* investigation of the physics of earthquake sources and for developing efficient seismic hazard reduction procedures. It was selected several years ago, after an Intenational Continental Scientific Drilling Program (ICDP) supported workshop (Cornet et al., 1997), as a site for developing an *in situ* laboratory, the CRL.

The Corinth Rift (Fig. 1), which separates the Peloponnesus from continental Greece, is a 110-km-long, N 110° E-oriented graben, bound by systems of very recent steeply dipping normal faults less than 2 Myr old (Armijo et al., 1996; Jolivet et al., 2004; Le Pichon et al., 1995). This structure is the site of continental break-up, with up to 1.5 cm yr^{-1} of north-south extension and a few millimeters per year uplift of the southern shore (Avallone at al., 2004; Briole et al., 2000; Pantosti et al., 2004). This rapid opening is associated with a shallowly north-dipping seismic zone located at depths ranging from 6 km to 12 km (Bernard et al., 2006; Gautier et al., 2006; Rigo et al., 1996). Five events with magnitude larger than 5.8 have been recorded in this region within the last forty years. The rifting is associated with the subduction to the southwest of Peloponnesus but also possibly to the propagation of the North Anatolian Fault.

CRL (www.corinth-rift-lab.org; Comptes Rendus Geosciences, 2004) is located in the vicinity of the city of Aigion, some 40 km east of Patras. It covers an area about 30 km × 30 km, extending across the gulf between Aigion on the southern shore and Eratini on the northern shore. This area was chosen for several reasons:

- The local strain rate and the microseismicity are highest (1.5×10^{-6} per year);
- The faults in this area have not been the site of any earthquake of magnitude larger than 5.5 for more than a century (three centuries for the western part). Further, from GPS data analysis, these faults are considered to be in the final stage of their seismic cycle (a few decades) and in a state of accelerated strain (Bernard et al. 2006);
- These faults were recently loaded by the 1995, magnitude 6.2, so-called Aigion earthquake, at the north eastern edge of the area (Bernard et al., 1997);
- The gulf is less than 8 km wide there, allowing on-land access to instrumented sites.

The CRL involves the monitoring of seismic activity with a network of twelve three-component (2-Hz) seismic stations and three broadband stations; the monitoring of surface deformation by continuous GPS, high resolution surface

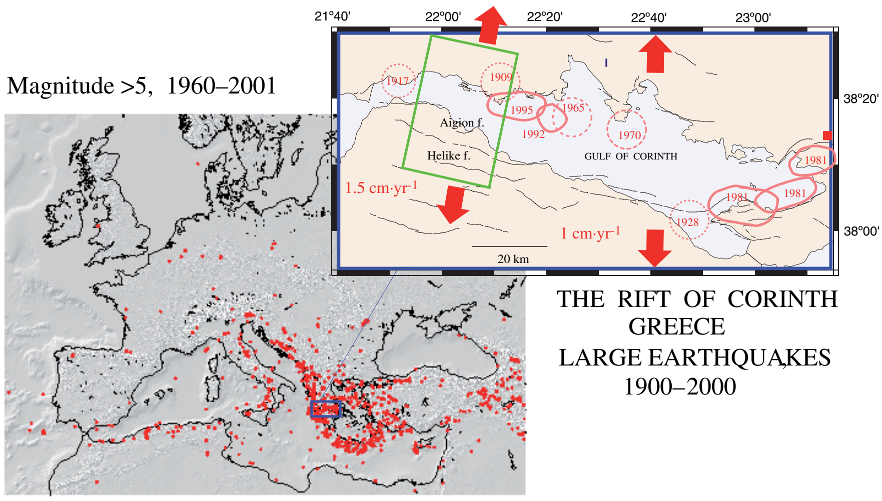

Figure 1. Geodynamic context of the Corinth Rift zone.

tiltmeters, and downhole strainmeters; and the monitoring of water level or flow rate variations of natural springs and their changes in chemical composition, including rare gas content. In addition, it involves deep boreholes (presently two) for better characterization of the geological structure and for *in situ* monitoring of fluid-fault interactions.

One of the goals of the CRL is to understand the geometric connections between the outcropping steeply dipping fault planes and the deeper shallowly dipping seismogenic zone. Another goal is to explore the relationship between seismic and non-seismic deformation, with particular attention to the role of circulating fluids, for only about 40% of observed deformations (last five years) can be accounted for by the cumulated seismic activity.

More than five years of observation are presently available (Fig. 2). Of particular interest is the microseismic crisis (maximum magnitude 3.5) along the Aigion fault, that started about one month after the 1000-m-deep AIG10 borehole (Cornet et al., 2004) modified the hydraulic conditions in the upper part of the fault (October 2004). The destabilization of the fault in its upper portion is evidenced by minute (40–80 Pa) pressure drops (Fig. 3) dynamically triggered by large distant earthquakes (magnitude ≥8 with epicenters located more than 10,000 km away). The crisis, which lasted about five months, migrated westward and downward and generated more than 2000 events, many of which are multiplets. Preliminary results outline the existence of subvertical slip planes, some of which are strike slip (Bourouis et al., 2005; Cornet et al., 2005) as well as low dip fault planes. This is in contrast with the other most significant seismic crisis (2001) observed during the five-year life span of CRL existence that occurred in a zone that was thought to be inactive. The 2001 crisis is much more localized and is thought to have been associated with upward fluid motion (Lyon-Caen et al., 2004).

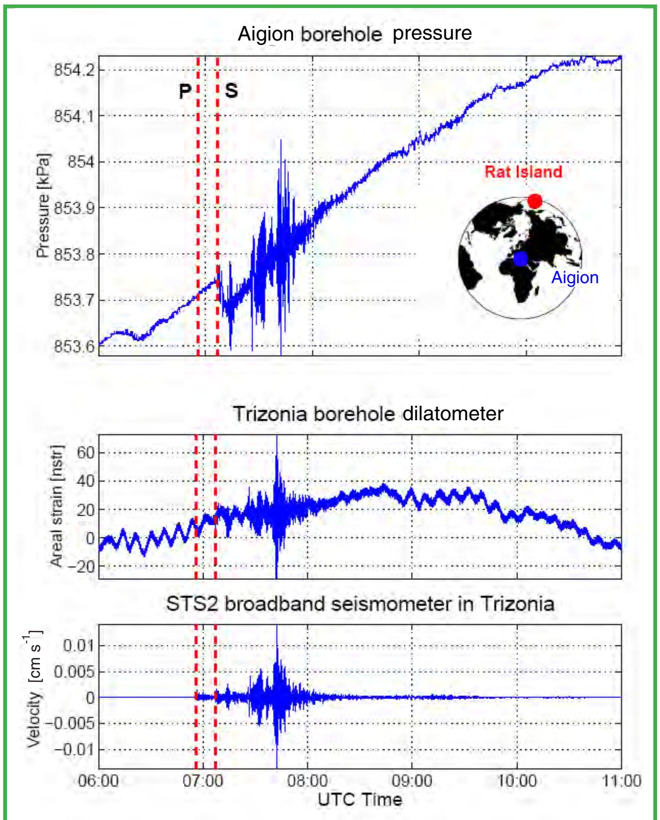

Figure 3. Pressure gauge readings in the 1000-m-deep AIG10 well that intersects the active Aigion fault at 760 m. Response to the S-waves generated by the Mw7.9 17 November 2003 Rat Island earthquake (Aleutian Isles). Seismic waves are recorded because of S-P conversion (Doan and Cornet, 2007). We also present data acquired 10 km north of the site. The borehole dilatometer and the broadband seismometer record the seismic waves, but do not display any anomaly, indicating that the pressure drop is induced in the vicinity of the AIG10 borehole.

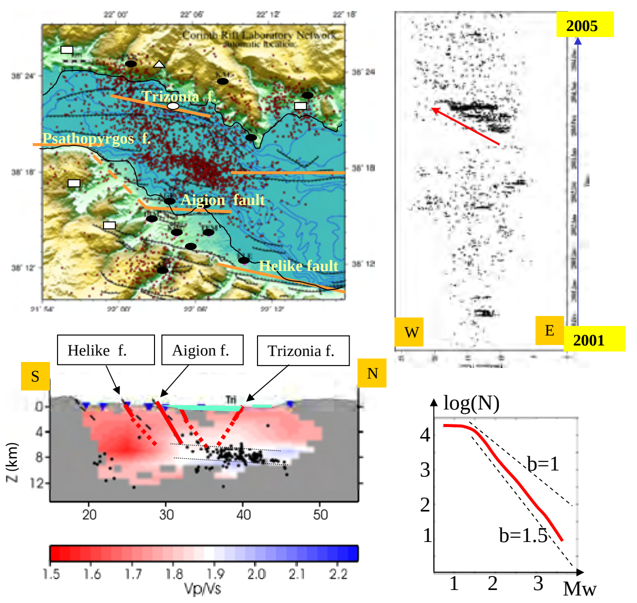

Figure 2. Seismicity at CRL. Top left: seismicity map 2000–2005, from automatic picking of CRL stations (black ovals). white oval: Trizonia STS2 station with real-time satellite telemetry. white triangle: broad band Czeck seismometer. white squares: broad band seismometers with real-time telemetry, planned summer 2006. orange lines: outcrop of main presently active normal faults. Top right: Time-space evolution of seismicity from 2000 to 2005 on an ESE-WNW axis. red arrow: migration of seismicity possibly linked with water diffusion (Cornet and Bourouis, and CRL Team, 2005). Bottom left: Vp/Vs ratio and 2000–2005 seismicity. red lines: major active faults (Gautier et al., 2006). Bottom right: red curve: Gutenberg-Richter law for the 2000–2005 period, with moment magnitude Mw.

The 1000-m-deep AIG10 well intersects around 760 m the 10-km-long Aigion normal fault that was reactivated during the 1995 magnitude 6.2 Aigion earthquake. Below the Aigion fault, the AIG10 well entered a karstic limestone with a 0.9 MPa overpressure, while the aquifer just above the fault was found also to be artesian with a 0.45 MPa overpressure. The fault is about 10 m thick and involves an argileous 60-cm-thick core. Within this clay zone, observed slip direction is consistent with the maximum principal stress component being normal to the main fault plane (Sulem, 2007).

Also significant is the observation of a transient creeping process (Fig. 4), preceding by about half an hour a local magnitude 3.5 earthquake in December 2002, which involved the shallow part of the Psathopyrgos Fault, at about 2 km in

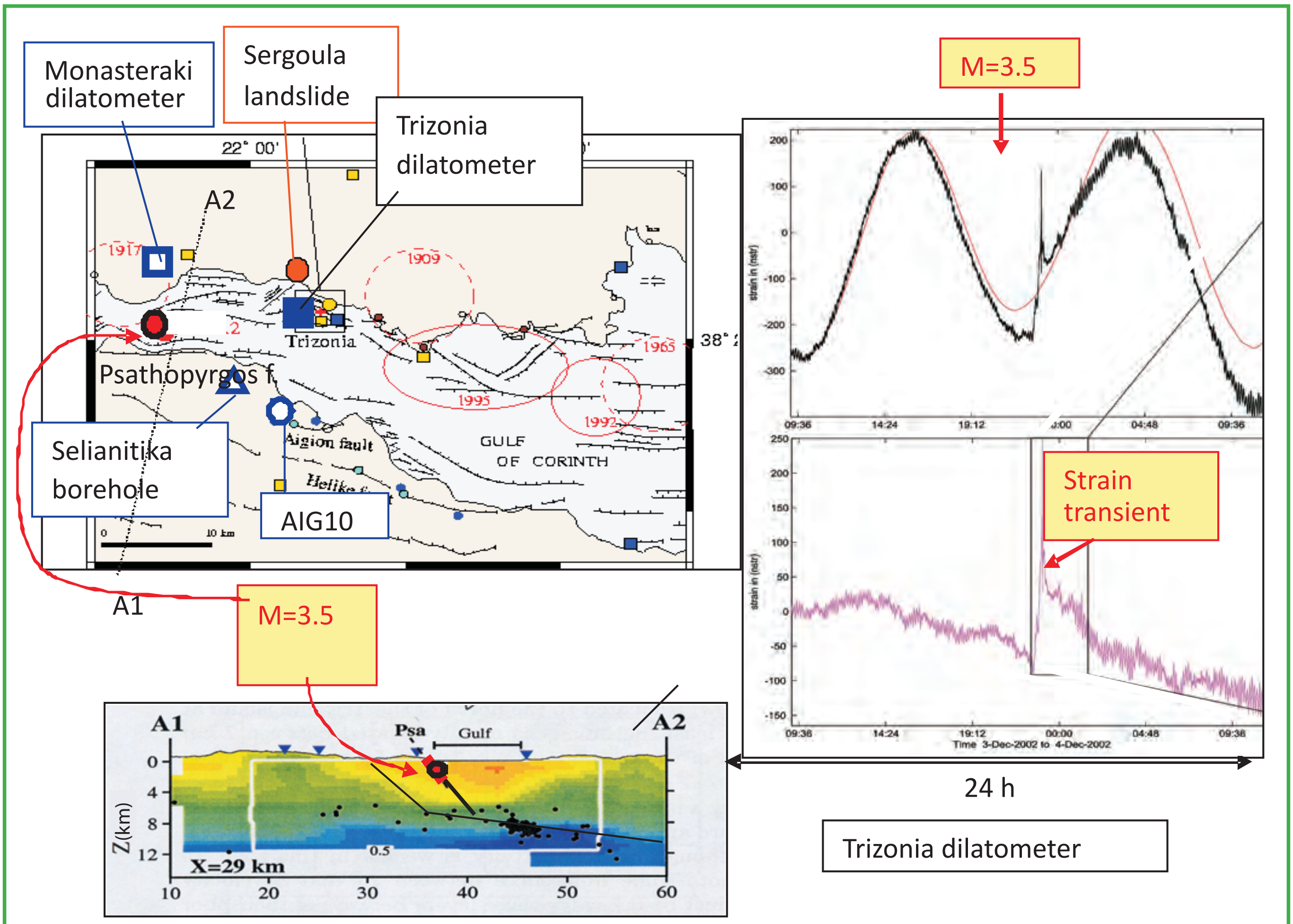

Figure 4 . Strain transients at CRL. Top left: Continuous strain-related observation array. Blue open circle: AIG10 borehole; Blue square: Trizonia dilatometer borehole; open blue square: Monasteraki borehole dilatometer, planned June 2006; Open blue triangle: Selianitika borehole; Yellow squares: continuous GPS; Blue dots: pore pressure in aquifers; Green square: geochemical station in aquifer; Green circle: radon probes on fault scarp. Black/Red circle: shallow 2002 earthquake coincident with the recorded strain transient; Top right: 24-hour record of the Trizonia dilatometer (3-12-2002). Red curve, top: synthetic of the tidal effect; bottom: data after tide removed. Note the one-hour-long transient dilatation, peaking with the M3.5 event (Bernard et al., 2006). Short period fluctuations are the pressure effect due to the free oscillations of the gulf. Bottom left: NS cross-section of the Psathopyrgos fault. Red and black circle: M3.5 event; Red segment: possibly creeping shallow Psathopyrgos fault, likely source of the strain transient.

depth (equivalent magnitude 5), i.e., well above the seismogenic zone of the area (Bernard et al., 2006). This earthquake was also the largest of a seismic swarm located about 15 km west of the CRL seismic network that lasted six weeks and involved deeper parts of the same fault.

The present plan is to deploy a complete suite of packers, high frequency (2.5 KHz sampling rate) 3C geophones, hydrophones (2.5 KHz sampling rate), high precision pressure transducers, thermistors, and tilt meters on both sides of the Aigion fault (February 2007). These data will be part of a feasibility study for drilling down to 5 km for sampling circulating fluids and monitoring high frequency signals within the seismogenic zone.

Acknowledgements

CRL was developed from 1999 to 2003 mostly through European funding and with the support of the International Continental Drilling Program for the drilling of AIG10. It has benefited greatly also from continuous support from the French National Centre for Scientific Research (CNRS) since 1999.

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http://www.corinth-rift-lab.org

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