THE CORINTH RIFT LABORATORY: MONITORING OF ACTIVE FAULTS

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Introduction

In their aim to understand the hydraulic behavior of faults and fractures, and their changes with stress variation, geoscientists are still poorly armed. On the one hand, data indicate that the rheology of faulted strata plays a major role: shale may create clay smearing, whereas, at temperatures over 80/100ºC, pressure solution processes quickly seal fractures in sandstones after rupture (Moretti et al., 2000). The hydraulic behavior of discontinuities also appears to be stress-dependent (Sibson, 1994), and may therefore change during the depletion of oil and gas fields. In order to clarify these issues, a complete dataset is necessary. European academic and private laboratories (as well as some oil companies) have decided to pool their efforts to collect such a dataset by creating the CORINTH RIFT LABORATORY (CRL), with the help of the EC. The goal is to investigate fault mechanics and their relation to fluid flow and earthquakes by continuous monitoring of strain, seismicity, fluid pressure and geochemistry — at the surface and at various depths in boreholes intersecting active faults. Around the world two others ambitious projects have been set up with the same goals but in another geological context: one to monitor the San Andreas fault, which is a strike slip fault outcropping in granite, and a second to drill the subduction zone in Japan. In our case, we drill extensional faults through sedimentary rocks; mainly limestones.

The CRL is centered on the south shore of the Corinth Rift. The Corinth Rift, which separates the Peloponnese from continental Greece, is a 105 km long, N100ºE oriented elongate graben, bounded by systems of very recent normal faults (less than 2 MY old). This structure is the most seismically active zone in Europe, and the fastest opening area of continental break-up, with up to 1.5 cm/yr of north-south extension, and more than 1 mm/yr of uplift of the southern shore (Tselentis and Makropoulos, 1986). The high rates of tectonic faulting and uplift correlate with the outcrop of very recent fault planes with large offsets, and to unique field exposures.

The shallowest seismogenic zone is at a depth of about 5.5 km. Earthquakes located beneath the northern shore usually indicate extensional failure of E-W planes dipping north 20º-40º (Bernard et al., 1995, Rietbrock et al., 1996). Fault planes exposed at surface in the Aigion area are considerably steeper, and fault dips in the range 55º-70º can be observed. The geometric connections between outcropping fault planes and the deeper seismogenic source are still an open question, and contrasting interpretations are feasible. The alternative hypotheses are: steeply-dipping faults abutting at a low-angle a seismically active detachment (Rigo et al., 1996), or a progressive downdip curvature of the fault planes into low-angle detachments (Doutsos and Poulimenos, 1992; Sorel, 2000).

A natural laboratory

The Gulf of Corinth has been studied for many years and the choice of this area has been facilitated by the existing database on seismology and deformation. The current effort is aimed at enlarging this database with additional surface data, and by drilling wells to obtain subsurface data at various depths

(Moretti et al., 2002). Up to now, the funding obtained to create the CRL (5 accepted EC projects: CORSEIS, DG-LAB, 3F-CORINTH, AEGIS and ASSEM, plus a couple of national efforts) covers:

- Surface arrays of accelerometres, GPS, seismic stations over an area of 30 by 30 km,
- Several shallow wells for strain, stress and fluid flow monitoring
- High resolution tiltmetres
- 4 reflection seismic lines
- Field geology data with fault zone analyses and sampling
- Repetitive HR gravity acquisition
- Monitoring of active fault in outcrops by extensometers (TM71 gauge)
- Trenches through the Helike faults and study of the historical seismicity thanks to the rich archeological records on the area
- Array of shallow wells in soft soil (5 wells between 20 and 200 metres near Aigion harbour)
- 3 wells, 500 to 1,200 metres deep, on active faults, two of them being fully instrumented so as to conduct hydraulic interference tests which will help to characterize fault hydraulic conductivity at a multimeter scale. The fault zone will be cored (+ logging and borehole imaging data: DSI, FMI, BHTV…)
- Permanent geochemical stations on aquifer and artesian wells.
- Sea bottom fault and fluid monitoring
- Data transfer and storage, data base management, cross-training with IT specialists.

A total of 25 European groups are involved in the Consortium.

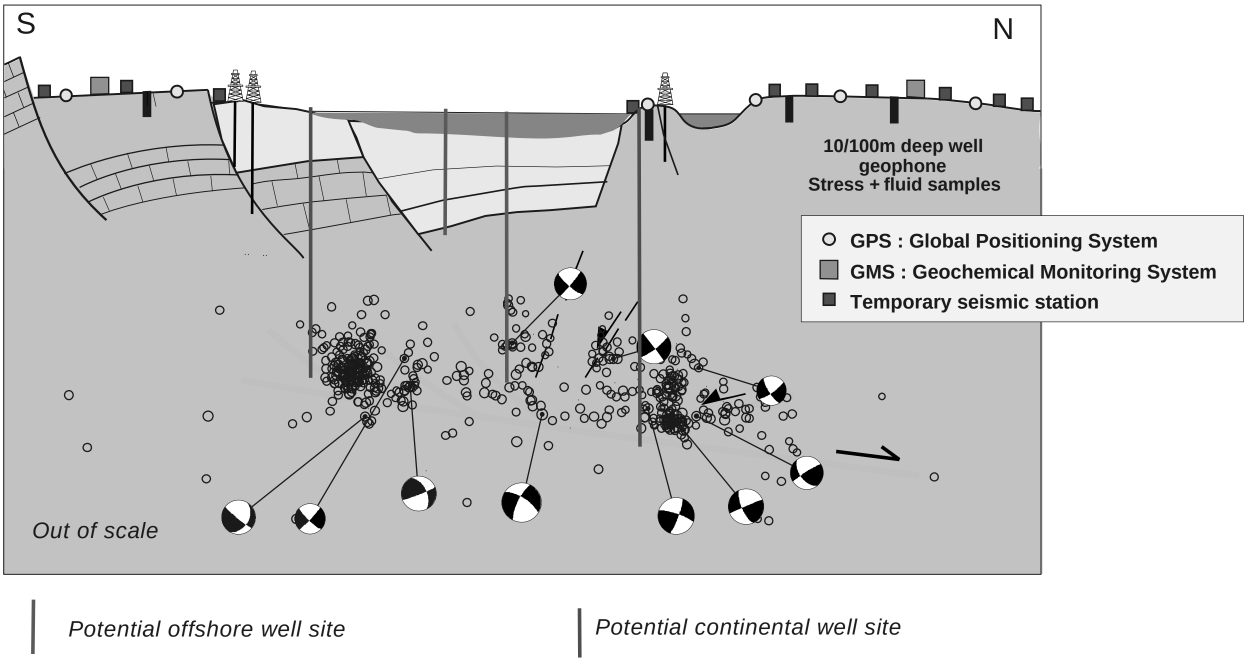

Fig 1: Schema of the laboratory, the dark wells are scheduled for 2002, the deepest ones are future prospects. Dark gray: Gulf of Corinth, light gray: synrift deposits, intermediary one: ante-rift, mainly limestones in the first 3 km. Seismogenic zone by Rigo et al. 1996.

Our goal is to obtain a complete record of stress, strain and fluid flow versus time in, above, and around an active fault plane

Fractures, Fluid and fluid-rock interaction

In order to characterize the fractures related to the recent normal faults, field work has been done on the outcropping faults. The Helike and Pirgaki faults are located just south from the Aigion fault that will be drilled and have a similar history for the recent time. The 3 are still active and affect both ante and syn-rift deposit but, due to erosional processes, the outcrops are located at different levels. A carefull study of the fractures allowed us to define the damaged zones and the hydraulic characteristics of the various zones (gouge, damaged zone) have been measured.

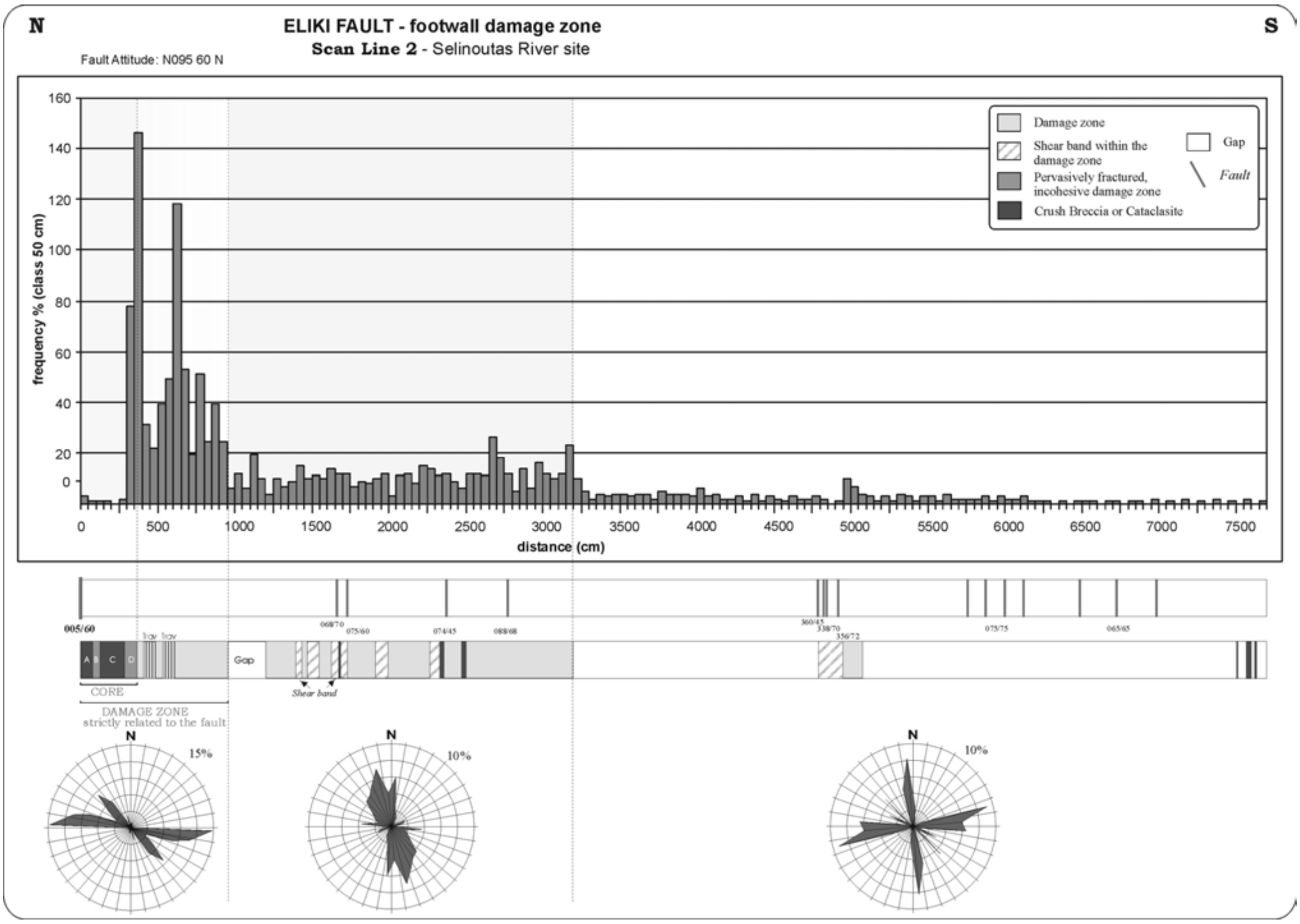

Fig2: Fractures in the limestones in the foot wall on the Helike fault

According to our observations, overall architectures of studied fault zones are conduit fluid flow systems, because of open fractures in the damage zone would act as a conduit for flow parallel to the fault zone. Nevertheless, both highly cemented breccia or cataclasite, and clay-rich gouge in the core would act as barriers to flow normal to the fault zone. These results are confirmed by some water wells, bored on the Heliki hangingwall. According to their distance from the fault plane, they go through the fault plane and core, which acts as a barrier to perpendicular fluid flow, and pump water from the limestone damage zone, which display a high fracture porosity

Flow network in the gouge zone has been characterized by a large set of technique from the matrix porosity, by Hg-porosimetry, to the ruguosity of different structural planes, by laser-profilometry. All of theses parameters allow distinguishing different strain processes in different parts of the gouge zones controlling the geometry of the porosity network. The anisotropy of flow condition is defined at different scales from the major fault plane to the matrix and is characterized by a large inter-dependence between the different scales.

Comparison: subsurface & outcrops:

The well through the fault in Aigion will be done in July 2002 and the one on the Trizonia Island (near the northern shore) is scheduled to October 2002. We will present at the conference the first results of the fractures analyses on the core and boreholl image as well as the pumping tests and the log data. Comparison will be done with the data from outcrops

Acknowledgement:

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Additional informations: http://www.ifp.fr/corinth and http://www.corinth-rift-lab.org

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