Geologic, geomorphologic and geophysic approaches for the paleoseismological analysis of the Amer fault (NE Spain)

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ABSTRACT

In the frame of the Paleosis project (ENV-CT97-0578 EC) we studied three different zones in the Eastern Pyrenees. We present here the main conclusions of the performed work in one of these zones: the Amer fault. This fault probably associated to the first earthquakes of the seismic sequence of 1427-1428. It presents well defined geomorphologic evidences of recent activity. Detailed geophysics studies have been pursued in order to decide the precise sites, candidates to be trenched for paleoseismological analysis. The analysis of data provides non clear correspondences between the geomorphologic treats of recent deformation and the detected anomalies from geophysics -the important human activity has probably disturbed the relicted features-. Moreover, the sedimentation tax seems to exceed the probable co-seismic deformation rate since the last 4000 years BP. It seems in conclusion, that fault traces are probably too deep in order to be reached without an important ecological and economical impact.

KEYWORDS:

EASTERN PYRENEES,EARTHQUAKES,PALEOSEISMOLOGY.

1. INTRODUCTION

Although present day seismicity of the Eastern part of the Pyrenees is moderate, important earthquakes took place in the past. Namely, a destructive earthquake of MSK intensity VIII-IX (Olivera et al., 1994) occurred in the Central Pyrenees in 1373. Later on, a series of earthquakes caused considerable damages over a large area of the Eastern Pyrenees during the period 1427-1428 (Banda and Correig, 1984; Olivera et al., 1999).

The 1427 seismic crisis shows a clear alignment following a NW-SE direction; recently its damages distribution has been relocated after 8 differentiated events (Olivera et al., 1999b) and it can be related to the Amer normal fault. The 1428 earthquake with a maximum intensity of IX around of Queralps area and shallow focal depth (Banda and Correig, 1984) may be related to a W-E thrust due to the orientation of the damages along 40Km, between Camprodon and Puigcerdà villages (Philip et al., 1992).
In spite of the magnitudes of the 1427 quakes not greater than M=6, the presence of the quaternary deformation induced us to carry out a paleoseismologic investigation in this specific area (Fleta and Goula, 1998).

In fact, as no quaternary sediments are present in the mountainous region of the major 1428 event we did not plan a study for trenching in this region, but a study of indirect earthquake effects was undertaken, in particular on the growth of speleothems in the caves of the epicentral area (Carbon, 1999).

2. DIFFERENT APPROACHES FOR THE PALEOSEISMOLOGICAL ANALYSIS

Following the stated methodology in the Paleosis project and taking into account the results from the previous exploration trenches, we have performed geologic and geomorphologic studies, and geophysical surveys to determinate the most appropriate sites to carry out a paleoseismologic study (Fleta and Goula, 1999).

Geology

The Amer fault is a Late Neogene NW-SE trending normal fault. The fault plane is dipping 60º to the east and the average throw varies between 1000 and 1400m (Saula et al., 1996). In the slope originated by the fault scarp, quaternary debris slopes have been accumulated and the sediments transported by the streams recover the fault trace, and distally, these deposits are connected to alluvial materials of the main rivers and volcanic flows (Barnolas et al., 1994; Guérin et al., 1986) and lacustrine deposits (Bas valley case; Cros, 1986).

Geomorphology

The Amer fault is one of the most western faults of the system and affects a topographic high where erosion

have been dominant during the activity of the fault. Several geomorphologic features evidence its recent activity with triangular facets, drainage basins, alluvial fans and scarps in two different segments (Figure 1) (Ferrer et al., 1999a):

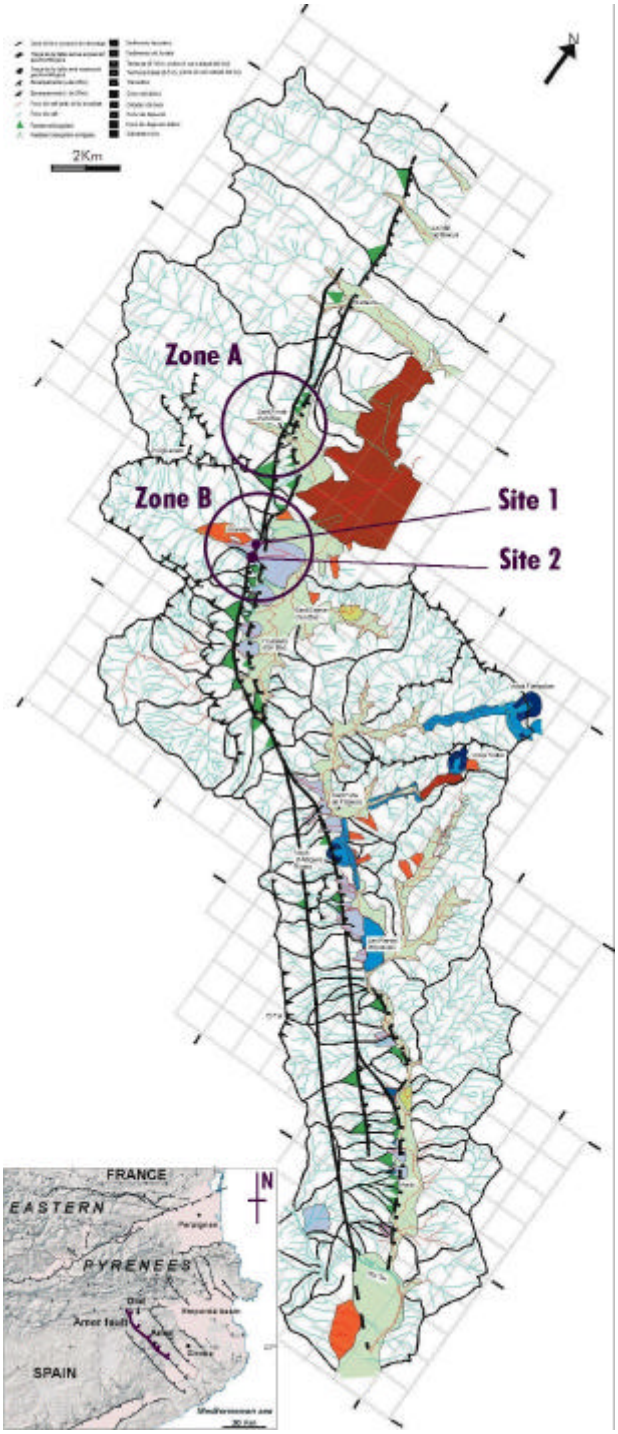

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Fig. 1 : Geomorphologic map of the Amer fault (Ferrer et al., 1999a). Location of the studied zones and sites.

- At least two generations of Plio-Quaternary triangular facets are present, the slopes of the most recent facets range from 17º to 31º.
- The drainage pattern along of the Amer fault present a typical geometry related to an active front, the average spacing index of the drainage basins varies between 0.28 and 0.56.
- Along the mountain front recent small alluvial fans have their apexes up-waters into the mountain front and cover the Amer fault.
- The alluvial fans show subtle scarps located along the fault line. These recorded anomalies in the Quaternary sediments that recover the fault trace can be interpreted as an effect of the more recent offsets of the Amer fault.

The geomorphologic scarps location were checked with topographic techniques such as the digital elevation model analysis of Catalunya (15x15m) (ICC, 1999a), a new ordered topographic restoration (10x10m) (SISYGSA, 1999), one classical total topographic station (Ferrer et al., 1999b) and two different campaign of DGPS -differential global positioning system- (Estruch, 1999). This analysis did not demonstrate the presence of clear features related to normal faulting processes; the anthropic activity has certainly perturbed the interpretation of the detected scarps.

Geophysics

We concentrated our investigations in two areas of the western slope of the Bas valley where the northern segment of the Amer fault is crossing two quaternary alluvial fans using the available information (Figure 1) (Cros, 1986; SGC, 1998; ICC, 1999b). Several geophysic techniques were used on the most probable sites to find surface ruptures: electric logs (a symmetric Schlumberger dispositif), dipole-dipole method (an AB and MN dispositif of 4m on the ground and 2m spacing grid in cross section) and seismic survey (1m of spacing and 45 sensor stations by shot) (Martínez et al., 2000). Finally, due to high water content and the coarse size of the materials we didn't obtain useful results from the performed GPR profiles (Gourgot and Molas, 1999).

The first selected area corresponds to the Sant Privat quaternary alluvial fan (zone A, Figure1). The geophysical prospecting (12 electrical logs) points out the presence of some anomalies of high resistivity. So, to verify these anomalies 10 tomography sections of average values of about 100 m length and 12 m in depth have been performed (ICC, 1999b).
The second area selected is located on the Joanetes quaternary alluvial fan (zone B, Figure 1), just in a more narrow fringe of the hypothetical surface trace fault; 10 electrical logs, 5 tomography and 2 seismic refraction profiles have been performed .

The best obtained results correspond to the Fusteria (Figure 2) and the Estruços sites (Figure 3) both on the Joanetes quaternary alluvial fan (sites 1 and 2, in the zone B of Figure 1).

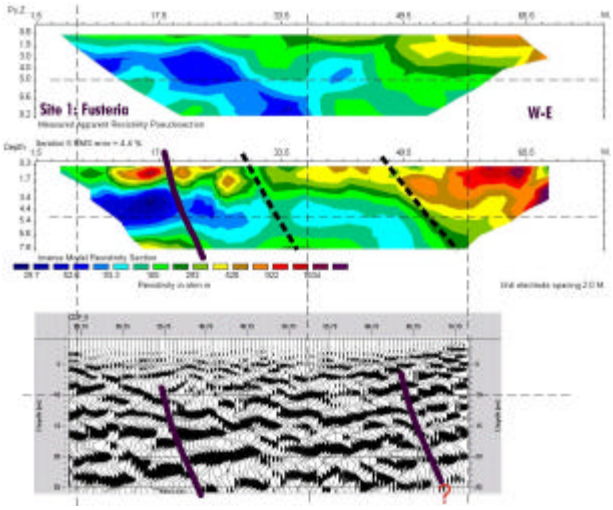

Figure 2 : Dipole-dipole pseudo-section, inverse model resistivity and seismic profile of the Fusteria site (1 in Figure 1). In dashed line are represented the anomalies from the tomography profile and in continuous line from the seismic interpretation. The interpretation point out some coincidences of the detected anomalies just in he middle of this profile.

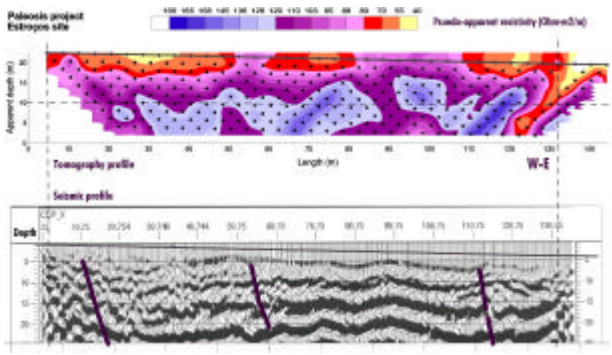

Figure 3 : Pseudo-section electric tomography and seismic profiles represented in depth of the Estruços site (2 in Figure 1). The anomalies in the pseudosection can be related to little contrasts of the higher ressistivity values that appears in the seismic profile (beginning and finishing parts).

The Estruços seismic profile (Figure 3) shows a great continuity of the seismic reflectors, although it is possible to recognise slight indications of the surficial ruptures of the signal located in quaternary sediments. The detected anomaly in the middle part of the profile coincides with a geomorphologic scarp.

3. DISCUSSION AND CONCLUSIONS

The Amer fault is over 30Km long. Only, two small segments of the fault, about 7 and 10Km seems to have been broken by 1427 earthquakes. This hypothesis is deduced from epicentral intensities of VII-VIII for the first event in the southern part and VIII (MSK) for the second one in the northern part (Olivera et al., 1999). So, according to the earthquake size no scarps are expected to form. Moreover, no scarps in the known historical primary sources are described.

The geomorphological analysis demonstrates the presence of two segments: 15Km long, for the northern segment, and 17Km long, for the southern one, with slightly different features. According to the assumed rupture length of the main events it would produce vertical displacement of about 0.5m (Wells and Coppersmith, 1994). If larger earthquakes occurred in the past (prior to 1427) producing fault scarps, there is some chance to succeed in trenching with paleoseismological purpose (Ferrer et al., 1999b). A vertical displacement 250-300m is obtained adding the height of the most recent facets during the Plio-Quaternary times. Assuming 2-5My for this period we can obtain an estimated slip-rate of the fault between 0.125-0.05mm/y. If we consider this displacement produced by seismic events causing scarps of 0.5 or 1m the recurrence intervals will range between 4000 and 20000 years.

The quaternary alluvial fans of the Bas valley are connected with the lacustrine deposits product of the closure of the Fluvià river by the last volcanic flow of the Croscat volcano of 9500 years BP age (Guérin et al., 1986). The dating of a peat level at 6m depth in the les Preses well in northern part of the Bas valley gives an age of 7340±80 years BP (Mallarach et al., 1986). So the sedimentation rate can be estimates at about 0.8 mm/year during the last 7000 years (Ferrer et al., 1999b).

From the above mentioned data we point out three main keypoints for the paleoseismological analysis:

- To understand the absence of the fault scarps on recent deposits along the fault line two aspects must be taken into account: a) the very recent age of all surficial deposits, b) the low fault slip-rate versus sedimentation rate. Assuming a sedimentation rate of the 0.5mm/y (a bit lower tan the sedimentation rate in a lake), a 0.5m high scarp would be totally covered after 2000 years of deposition, and a 1m high scarp after 4000 years. The recurrence intervals evaluated are 2 to 5 times larger than the time required to bury the scarps.
- The geophysical surveys do not suggest clearly the possible rupture in the quaternary upper levels.

- The performed exploration trenches pointed out the presence of coarse detritic deposits, reducing the possible location of low energy alluvial fan in order to prospect on fine sediments optimal for paleoseismological approaches. Therefore it seems very difficult and unlikely to reach the fault by trenching because the scarcity of sites with fine sedimentation, with accurate location of the fault, and with significant scarps.

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