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Sismological evidence of topographic site effects in 1909 Provence earthquake damage distribution

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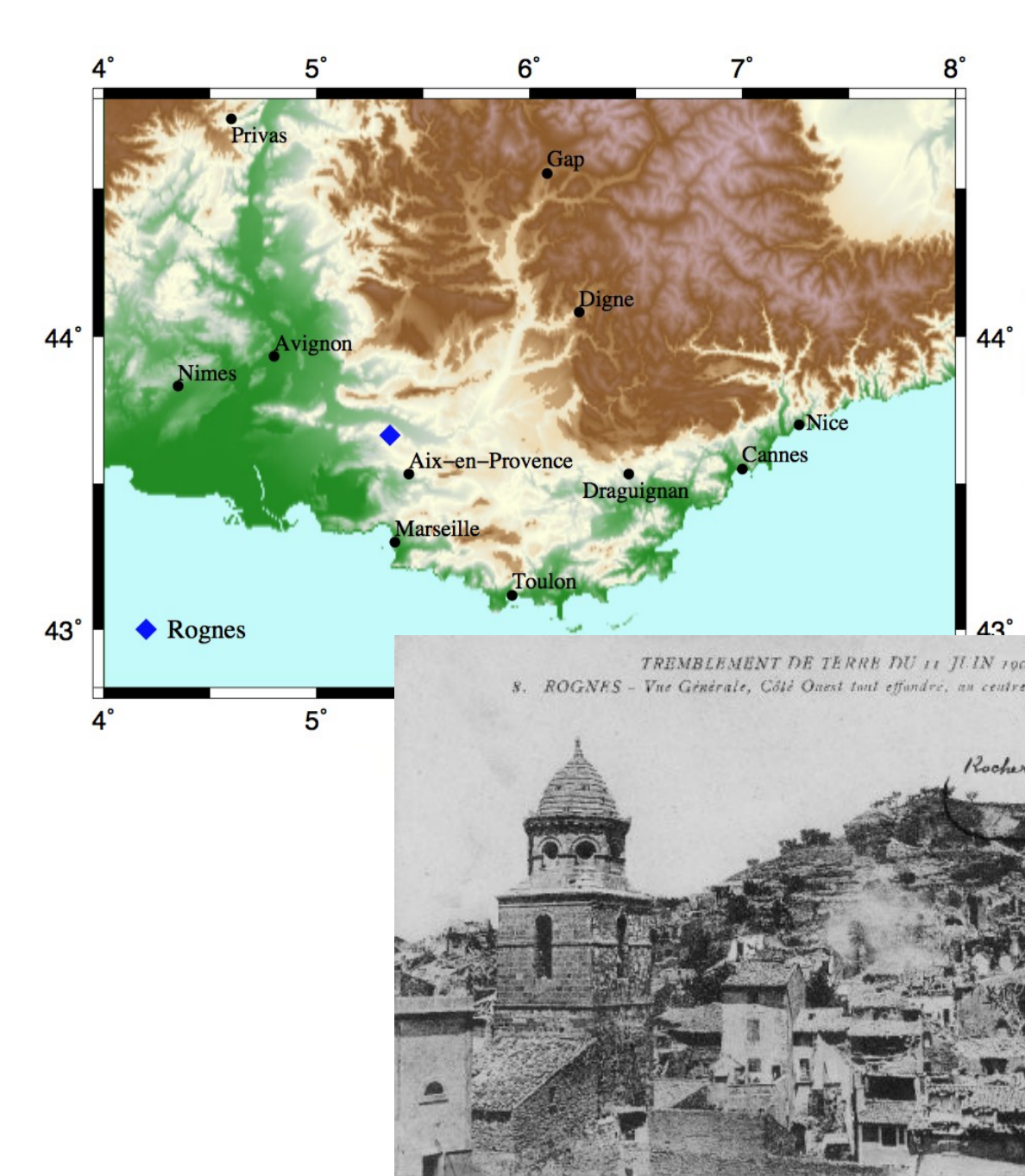
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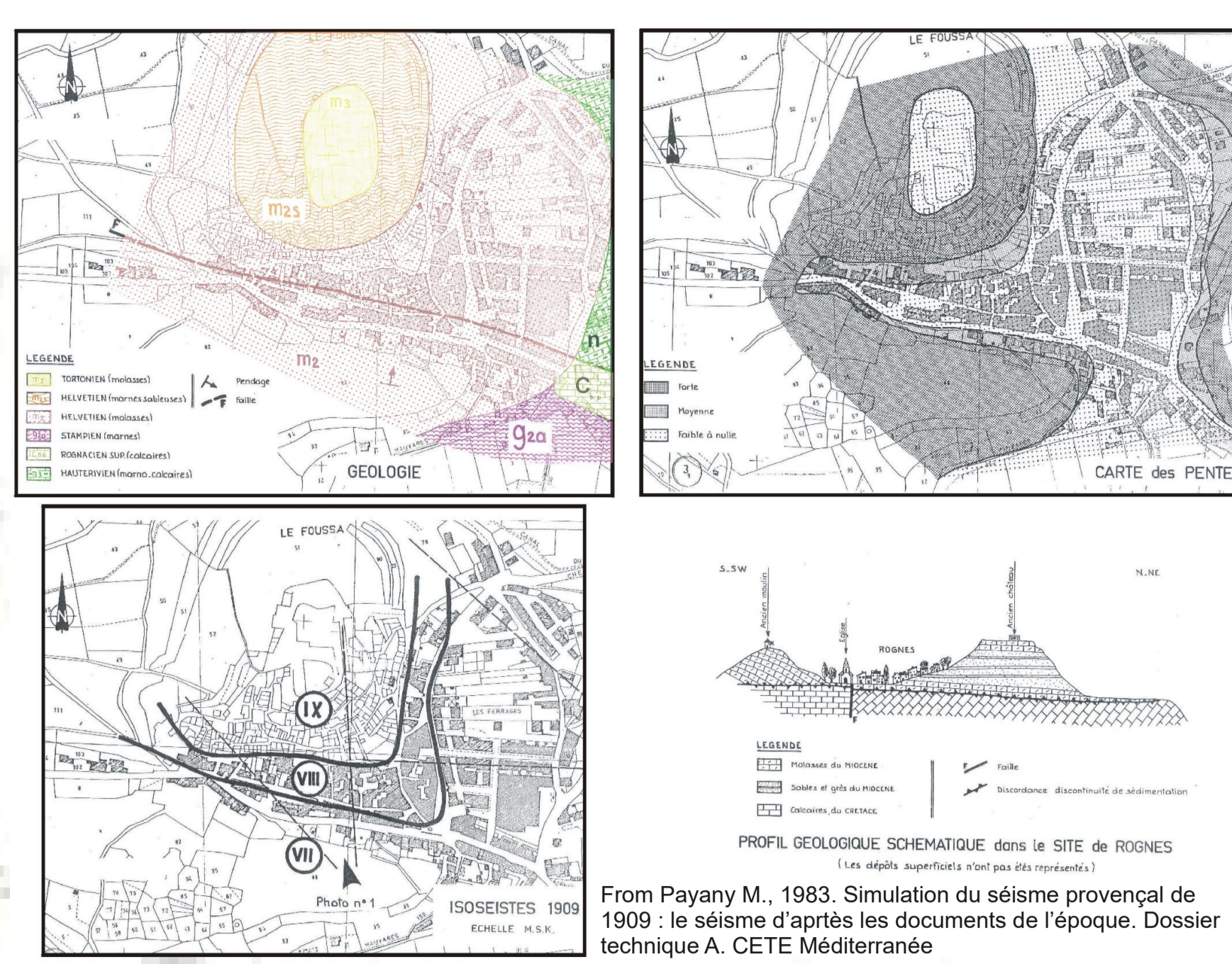
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During the 1909 Provence earthquake, a lot of municipalities exhibited strong variations in damage distribution. For some of them and Rognes in particular, the historical perched village suffered more damage than constructions built on the flat part of the territories.

While seismologists began to observe site effect importance in earthquakes, this 1909 damage distribution became the most famous French illustration of topographic site effect. But if ray theory explains that relief can indubitably focus waves and amplify seismic signal for specific wavelength according to the location on the slope, some doubts remain about the real impact of topographic effects in 1909 damage distribution. In order to evaluate the site effect in the city of Rognes, we set up several seismological field campaigns. Numerical simulation are also conducted to be compared to the experimental results. The main issues of this work is then :

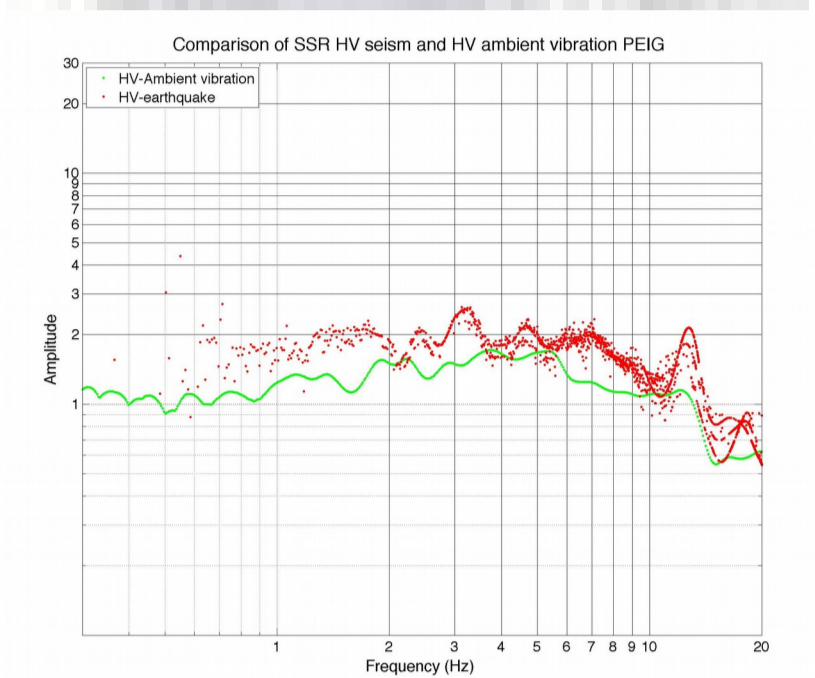
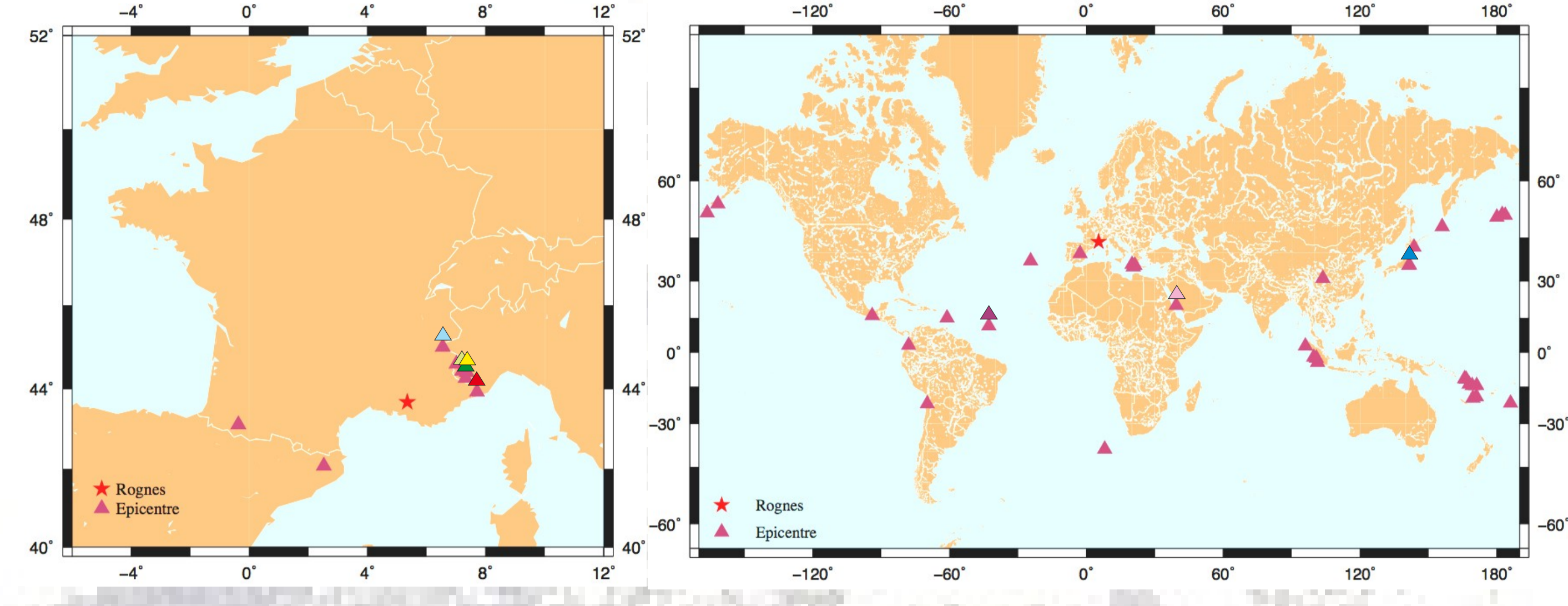
- To understand what really happened from a sismological point of view during 1909 earthquake : Is it justified to say that the observed damage in Rognes are linked to some topographic effect ?
- To test the experimental method: Is the "site/reference on earthquake" method (Borcherdt, 1970) able to state for the frequencies amplified by topography ?



Nine stations (Hathor3 and Le3D-5sec) are set up in the village of Rognes. The temporary network lasted already for 30 months and recorded continuously not only the world seismicity but also the ambient vibrations. It represents more than 1 To of data. Among this data, nearly 10 local earthquakes were well recorded, whereas 45 world event were detected until now.

Example of recorded PGA :

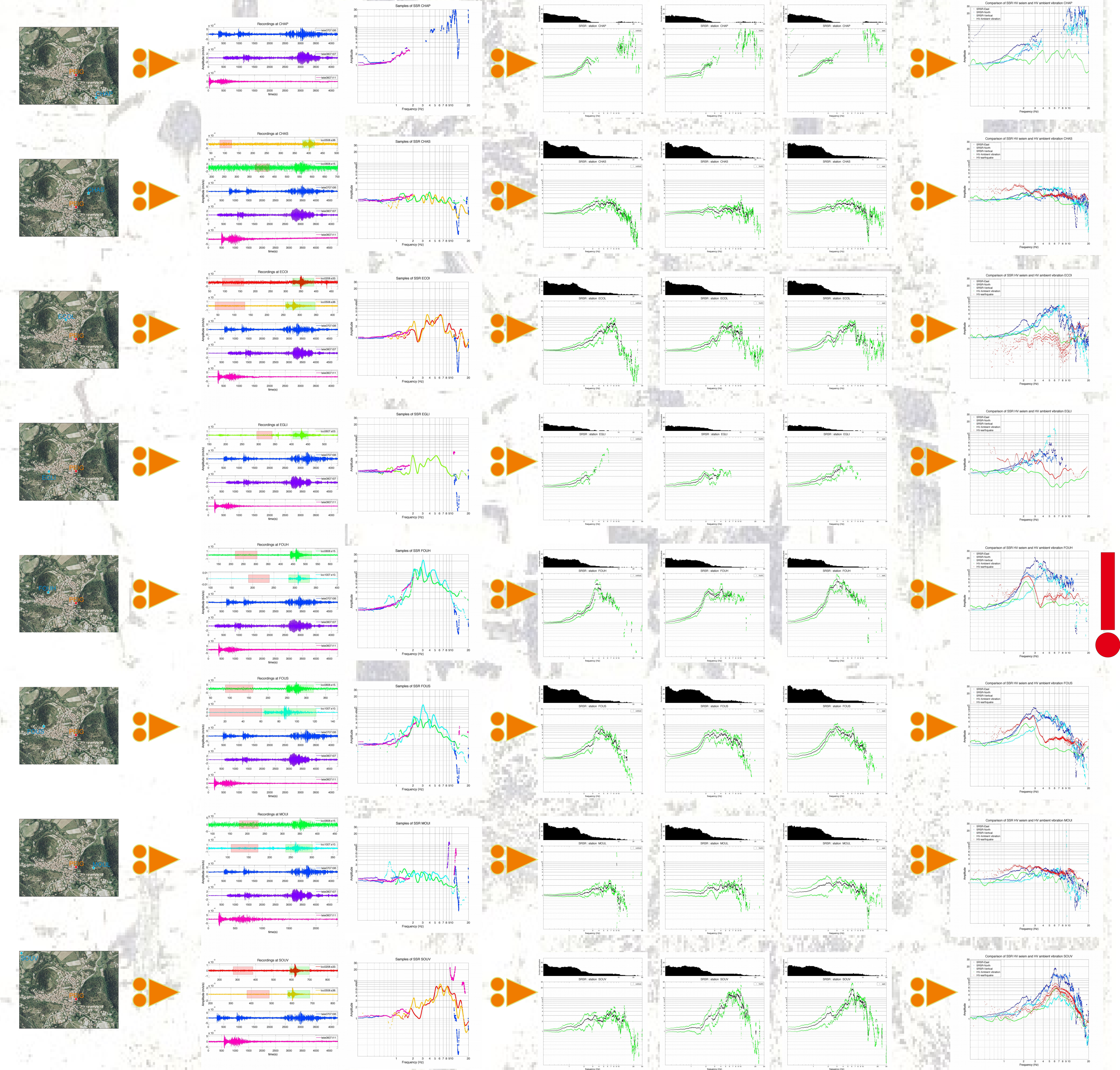
ID	mag	Distance FOUS (km)	chap	chas	ecol	egli	fouh	fous	moul	peig	souv
loc0607.e3	3.3	61.239	4.64E-05	3.23E-06	1.14E-05	1.22E-05	2.03E-04	9.17E-06	4.34E-06	7.89E-06	1.09E-05
loc1007.e10	3.4	178.31	3.87E-05	9.46E-06	9.46E-06	1.36E-05	9.22E-06	6.02E-06	9.42E-06	9.42E-06	9.42E-06
loc0508.e38	3.1	171.945	2.99E-05	3.43E-06	3.43E-06	9.99E-06	1.28E-05	3.22E-06	2.18E-06	2.18E-06	2.18E-06
tele0607.111	5.4	4.44E-02	1.99E-05	3.29E-06	2.58E-05	7.46E-06	3.11E-06	3.15E-06	4.27E-06	4.82E-06	6.75E-06
tele0607.17	6.5	9.149.11	2.02E-05	1.51E-05	1.89E-05	1.44E-05	1.39E-05	1.49E-05	1.58E-05	1.58E-05	1.58E-05



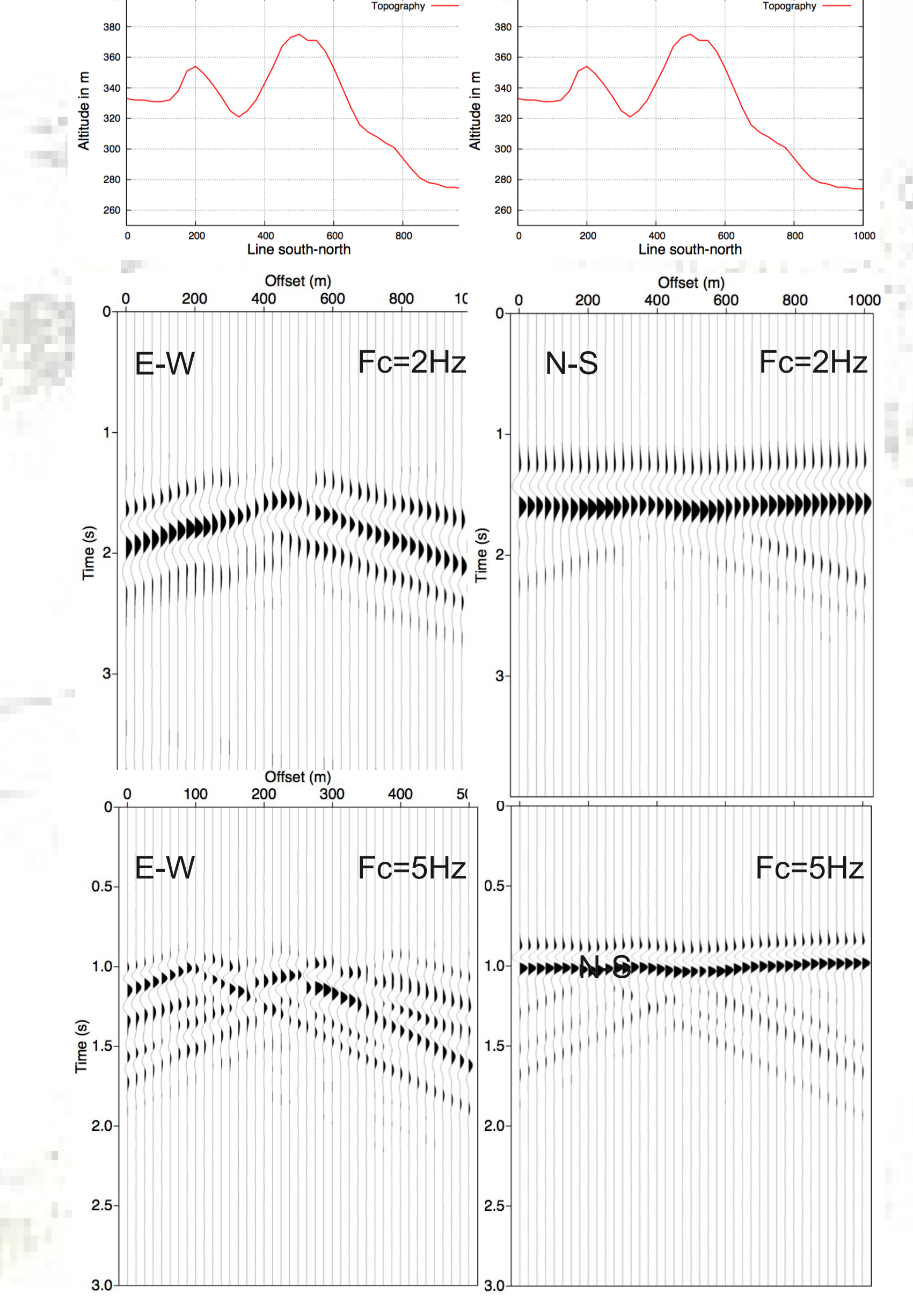
The data have been processed to obtain :
 - H/V spectral ratio on ambient vibration (HVSrN)
 - H/V spectral ratio on earthquake data (HVSrE)
 - Site/reference spectral ratio on earthquake data (SRSr)

Several stations (CHAP, ECOL, EGLI, MOUL and PEIG) exhibit both HVSrN and HVSrE flat curves. As PEIG recorded most of the earthquakes, we choose this station for the reference for the SRSr computation.

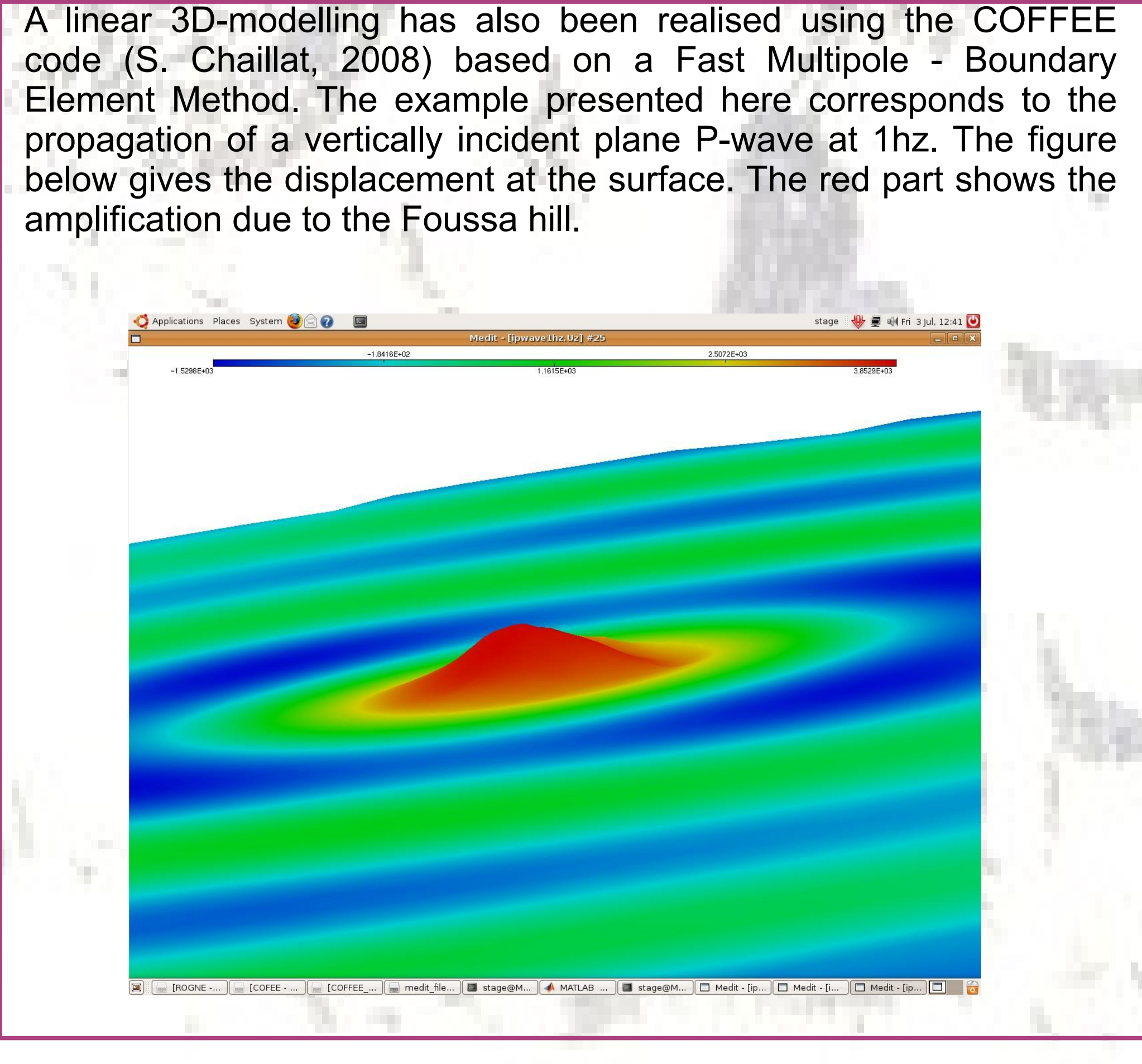
Site Example of computation SRSr Results Comparison



Numerical modelling (Preliminary results)



The numerical 2D-modelling of a vertical P plane wave has been achieved using the discontinuous Galerkin method. In this case, the medium is described by a regular mesh with a reference length of 25m (12.5m for 5 Hz case). The seismograms (velocity) are simulated at 41 sensors displayed at the surface with a step of 41m. The incoming signal is a Ricker of central frequency 2 and 5 Hz respectively.



First comments on the experimental results:

As field stations are still recording seismicity, all the available data are not yet processed. However, the available data have been processed according to 3 methods, now currently used for experimental microzonation : site/reference spectral ratio (SRSr); H/V on ambient vibration and H/V on earthquake. With these first results we observe that :

About the seismic amplification observed in Rognes :

- The SRSr curves on FOUH provide clear evidence of a strong amplification on the top of Fousa hill. (The weak) recorded earthquakes have been amplified up to 30 times as compared to the reference station PEIG, for frequency between 2 and 5 hertz. These frequencies could coincide with natural frequency of the stone masonry houses that collapsed. This amplification confirms the hypothesis that 1909 damages were linked to site effect. But at this stage, it is not possible to state for the nature of this site effect that may also be due to softer surface layer. The base of the hill (FOUS) provide the same kind of amplification with lower level. Does that implies that damage would have been even stronger if the village were built, as the castle, at the top of the hill ?

About the methodology :

The 3 kinds of curves (SRSr, HV SrN, HVSrE) computed for the 9 sites, can be sorted in 3 groups:

- A first group of sites (FOUH, FOCUS, SOUV) provide clear peaks with SRSr and H/V. As usually observed, the level of amplification is quickly when the level of amplification is important for SRSr and remains important at higher frequency.
- A second group of sites (CHAS, MOUL, PEIG) only provides flat curves both with SRSr (except PEIG) and HVSr.
- The last group (CHAP, AECOL, EGLI) show unusual discrepancy between SRSr and H/V curves that is not yet explained: the SRSr show amplifications when H/V remain flat. Is that relative to the position of the site on the topography ? to particular Vs profiles ? To particular ambient vibration context ?