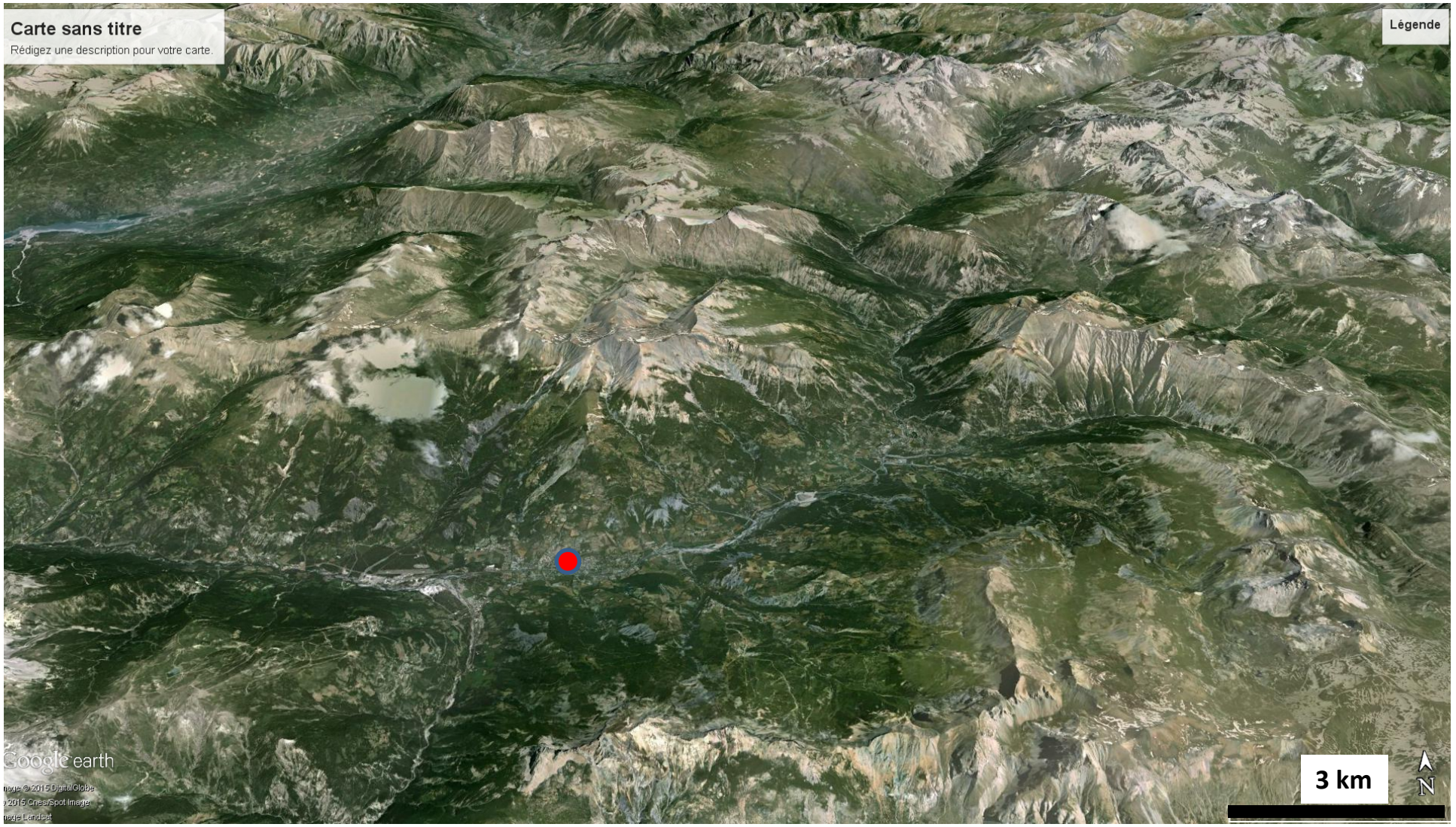
Barcelonnette in the Ubaye valley : the landscape results of large deformations during the alpine orogene (40-5 Myr in this area) and the succession of Quaternary glaciations. The sedimentary rocks are Meso and Cenozoic in age. Barcelonnette is à ~1000 m elevation and the surrounding summits around 2500 m.



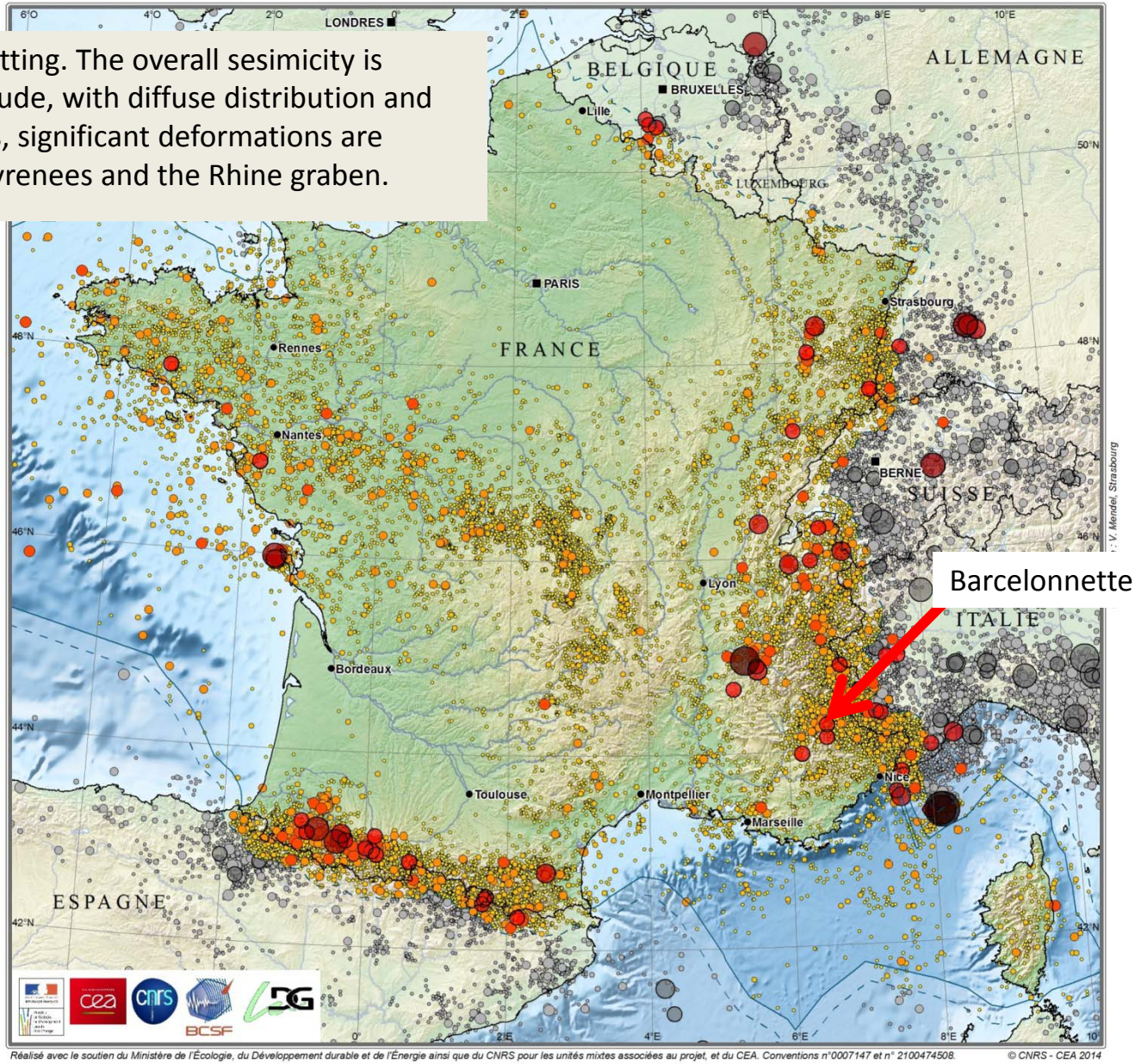
Earthquakes in Barcelonnette !

C. Larroque

France is in an intraplate setting. The overall sesimicity is mainly moderate in magnitude, with diffuse distribution and crustal depth. Nevertheless, significant deformations are recorded in the Alps, the Pyrenees and the Rhine graben.

Instrumental seismicity, 1962-2009.

http://www.franceseisme.fr/sismicite.html



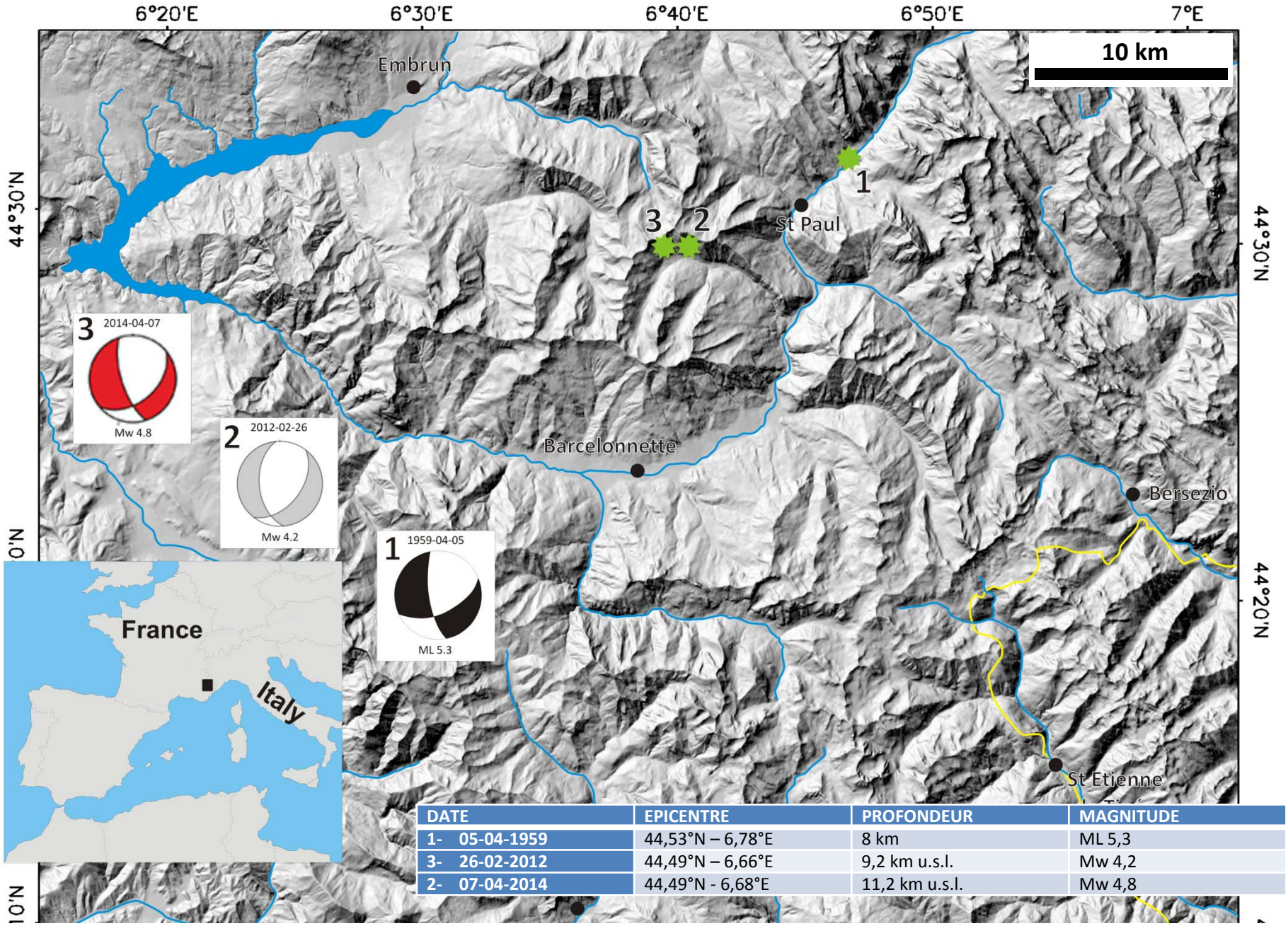
Sismicité catalogue SI-Hex

$M_w < 2,5$; $2,5 \le M_w < 3,0$; $3,0 \le M_w < 3,5$; $3,5 \le M_w < 4,0$; $4,0 \le M_w < 4,5$; $4,5 \le M_w < 5,0$; $5,0 \le M_w < 5,5$; $5,5 \le M_w < 6,0$; $M_w = 6,0$

En couleur : épicentres des séismes d'origine naturelle dans la zone SI-Hex (France métropolitaine et zone économique exclusive en mer (ZEE), avec élargissement de 20 km), ainsi que les séismes ressentis en France avec une intensité EMS-98 ≥ IV (BCSF). *En grisé* : épicentres des séismes hors zone pour lesquels une magnitude M_w a été calculée dans le cadre du projet SI-Hex.

0 50 100 km

3 moderate earthquakes occured in the Ubaye valley since 1959. They are well characterised thanks to the local seismologic network. Their focal mechanisms are very similar : extensional with a small strike-slip component.



DATE	EPICENTRE	PROFONDEUR	MAGNITUDE
1- 05-04-1959	44,53°N – 6,78°E	8 km	ML 5,3
3- 26-02-2012	44,49°N – 6,66°E	9,2 km u.s.l.	Mw 4,2
2- 07-04-2014	44,49°N - 6,68°E	11,2 km u.s.l.	Mw 4,8

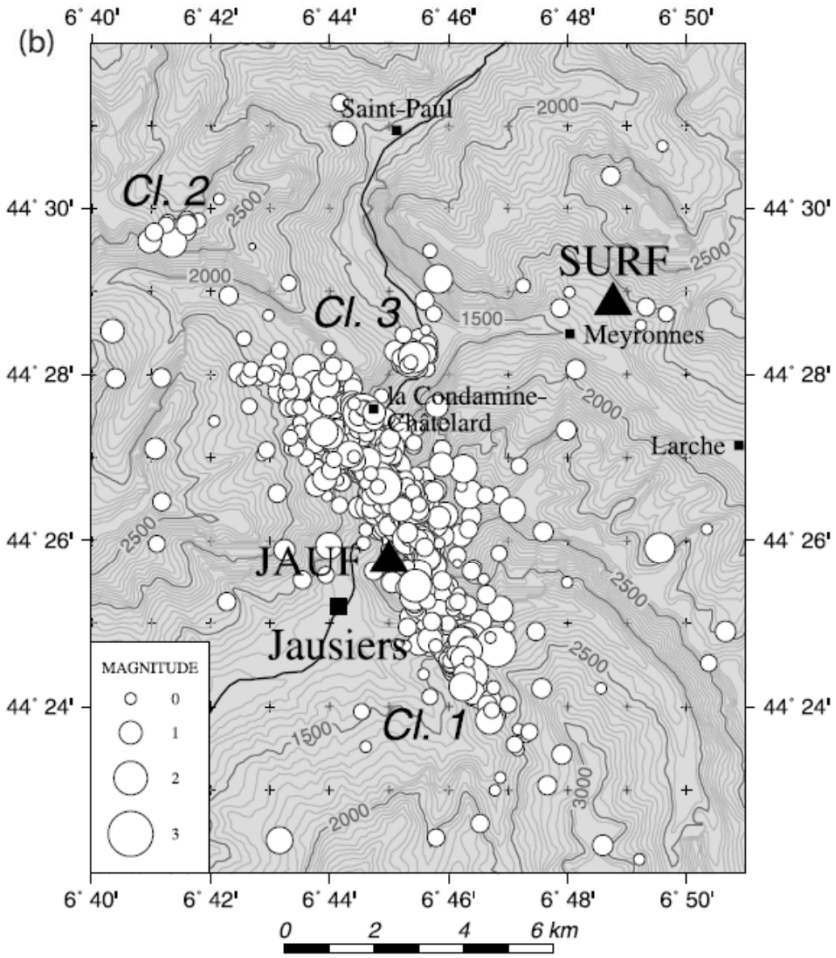
Seismic swarm 2003-2004

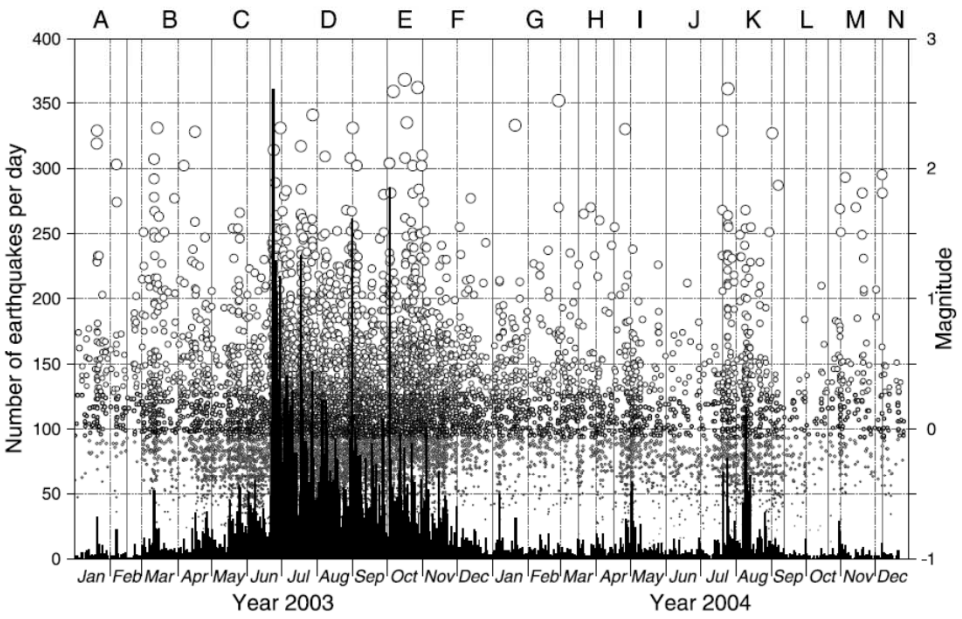
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, B11304, doi:10.1029/2006JB004878, 2007

Click Here for Full Article

The 16,000-event 2003–2004 earthquake swarm in Ubaye (French Alps)

Liliane Jenatton,[1] Robert Guiguet,[1] François Thouvenot,[1] and Nicolas Daix[1]

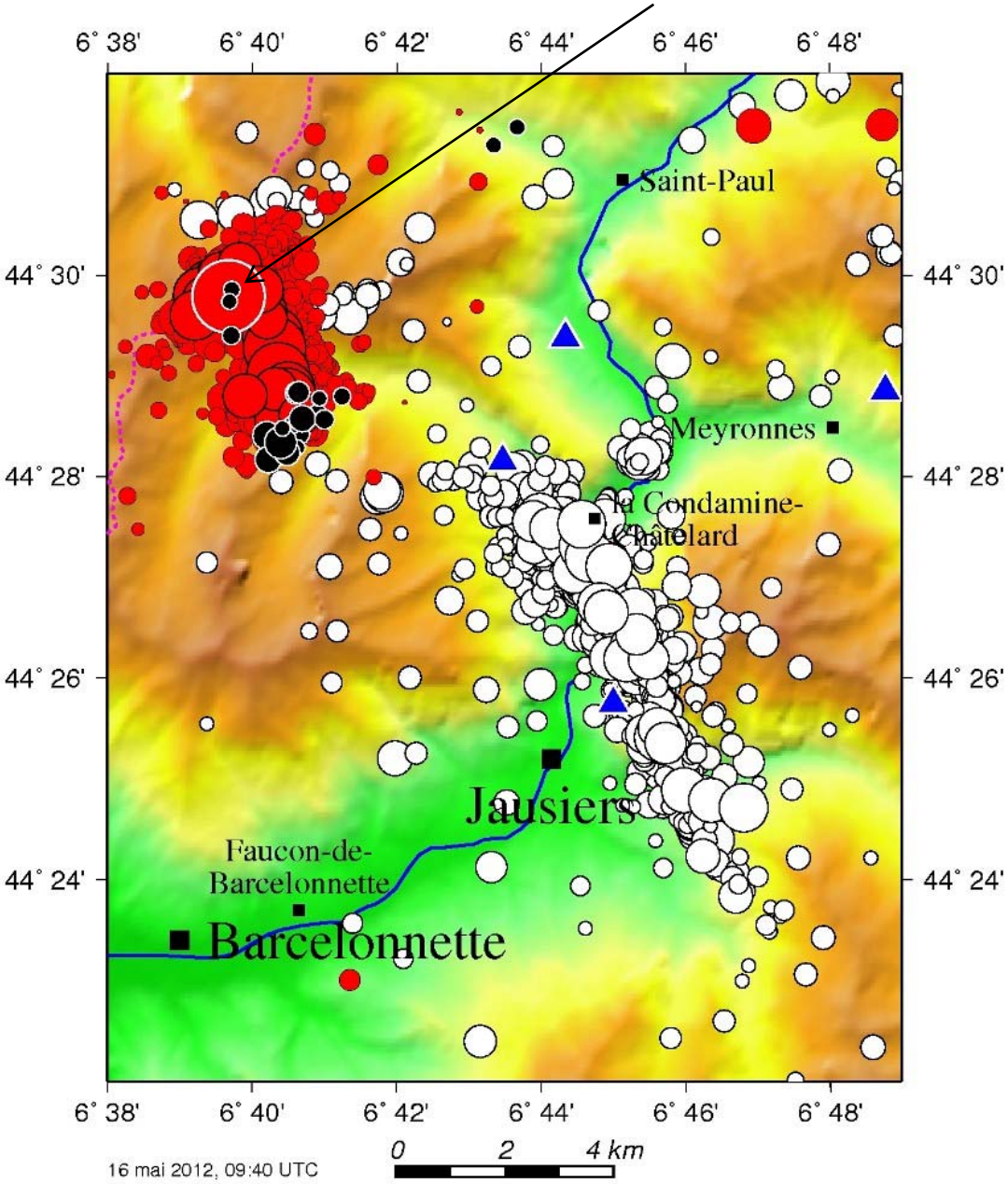




An exceptional swarm occured in 2003-2004 10 km east of Barcelonnette. More than 16 000 earthquakes of magnitude between 0 and 2.7 and shallow depth were recorded.

The distribution of the epicenters are rectilinear and suggests the activation of a fault at depth rather than volumic diffuse cracks.

Mainshock 2012 + seismic swarm ?

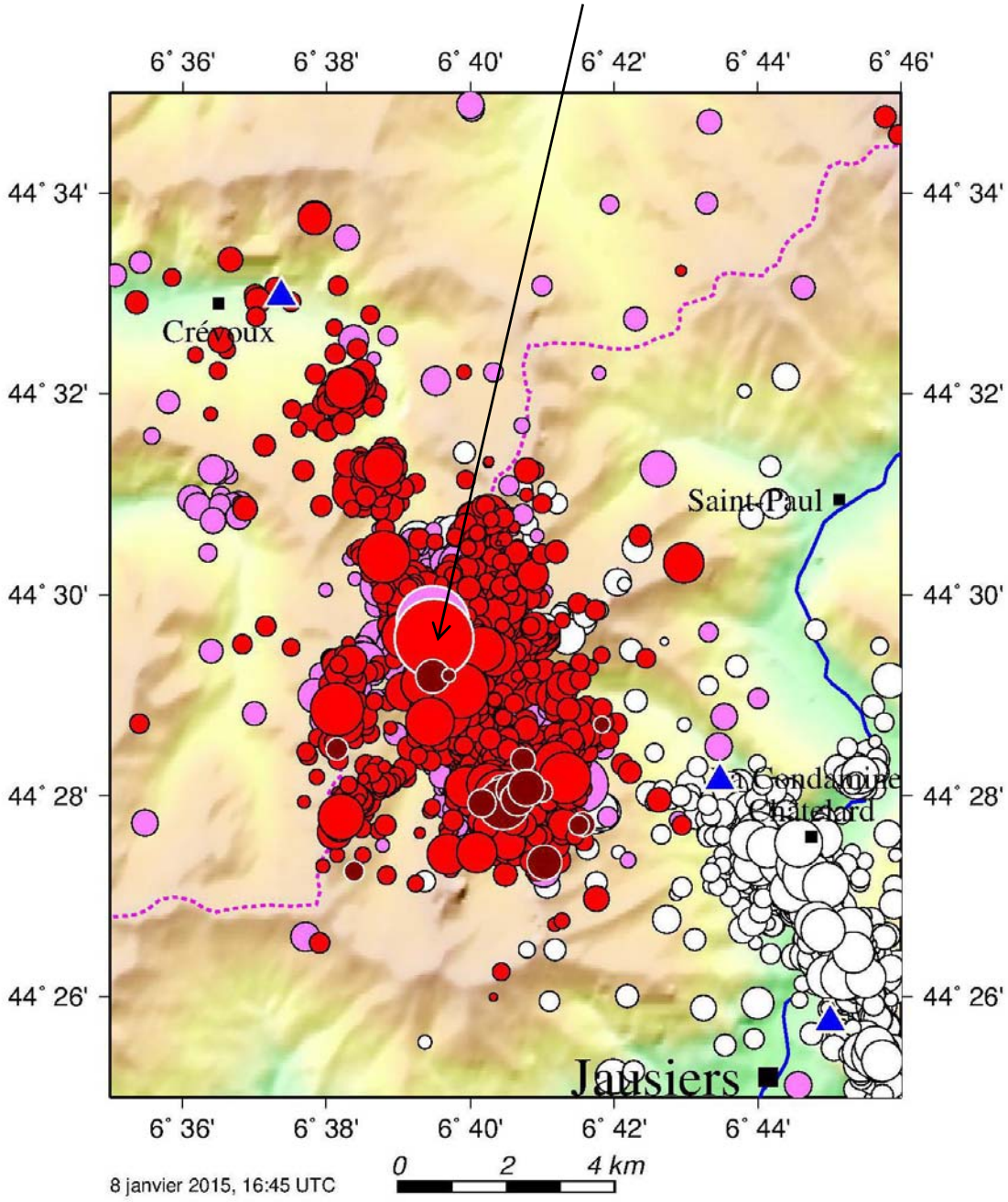


After several years of relatively low activity, the area was struck the 26 february 2012 by a Mw 4.2 earthquake (the big red).

This event was followed by more than 5000 small earthquakes in the following two years (in red and black on the picture, in white are the 2003-2004 swarm). Taking into account the long period, theses small earthquakes cannot be considered as afterschoks of the main February one.

François Thouvenot, IsTerre
http://sismalp.obs.ujf-grenoble.fr/

Mainshock 2014 + seismic swarm ?



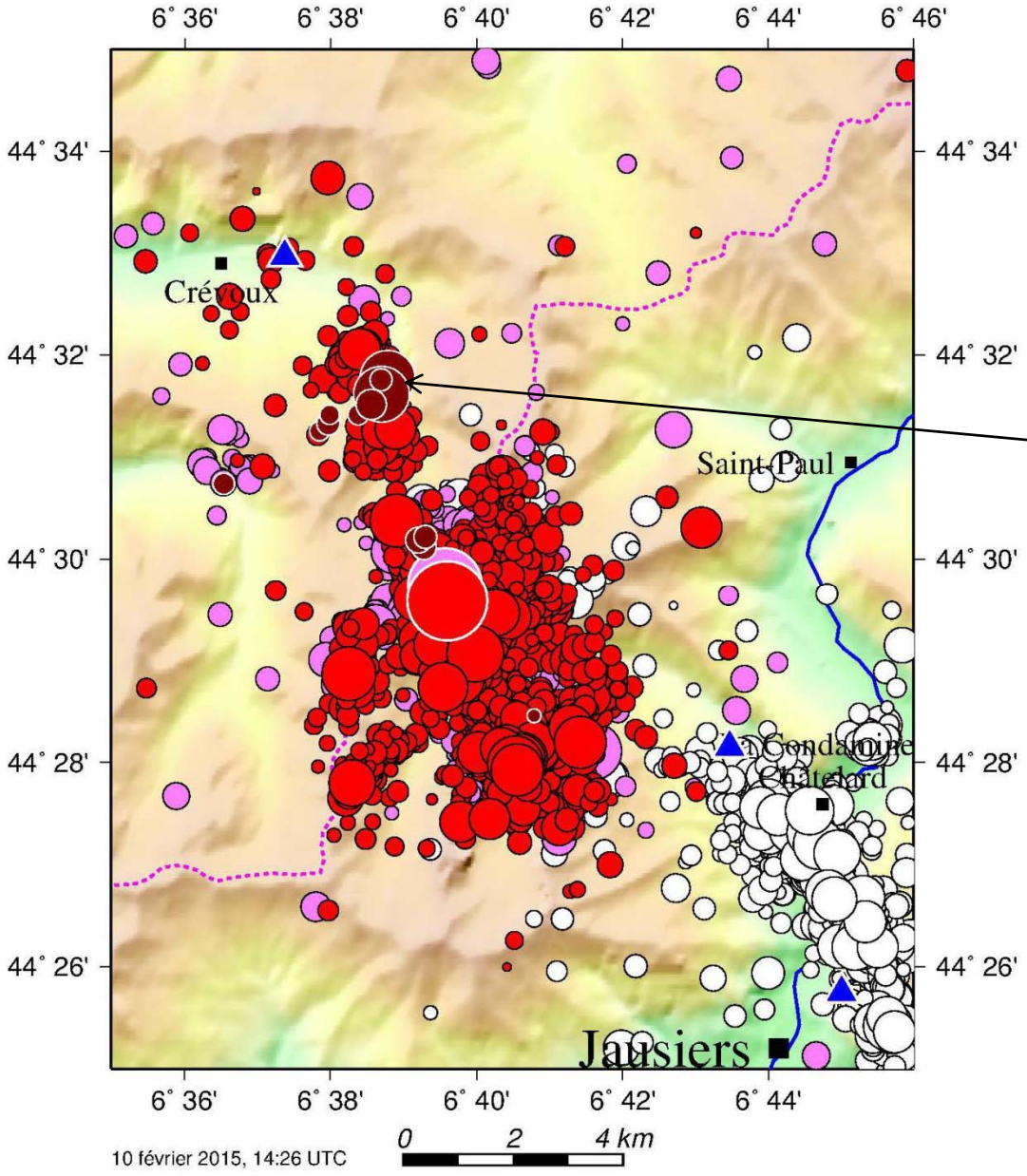
On the 7 april 2014, a new moderate event of Mw 4.8 occurred (big red circle), exactely at the same place than the 2012 event and 2 km deeper.

It was also followed by a swarm (more than 5000 thousand earthquakes between april and september 2014 in red) that continue today.

In pink the 2012 sequence, in white, the 2003-2004.

François Thouvenot, IsTerre
http://sismalp.obs.ujf-grenoble.fr/

The 10 February 2015…

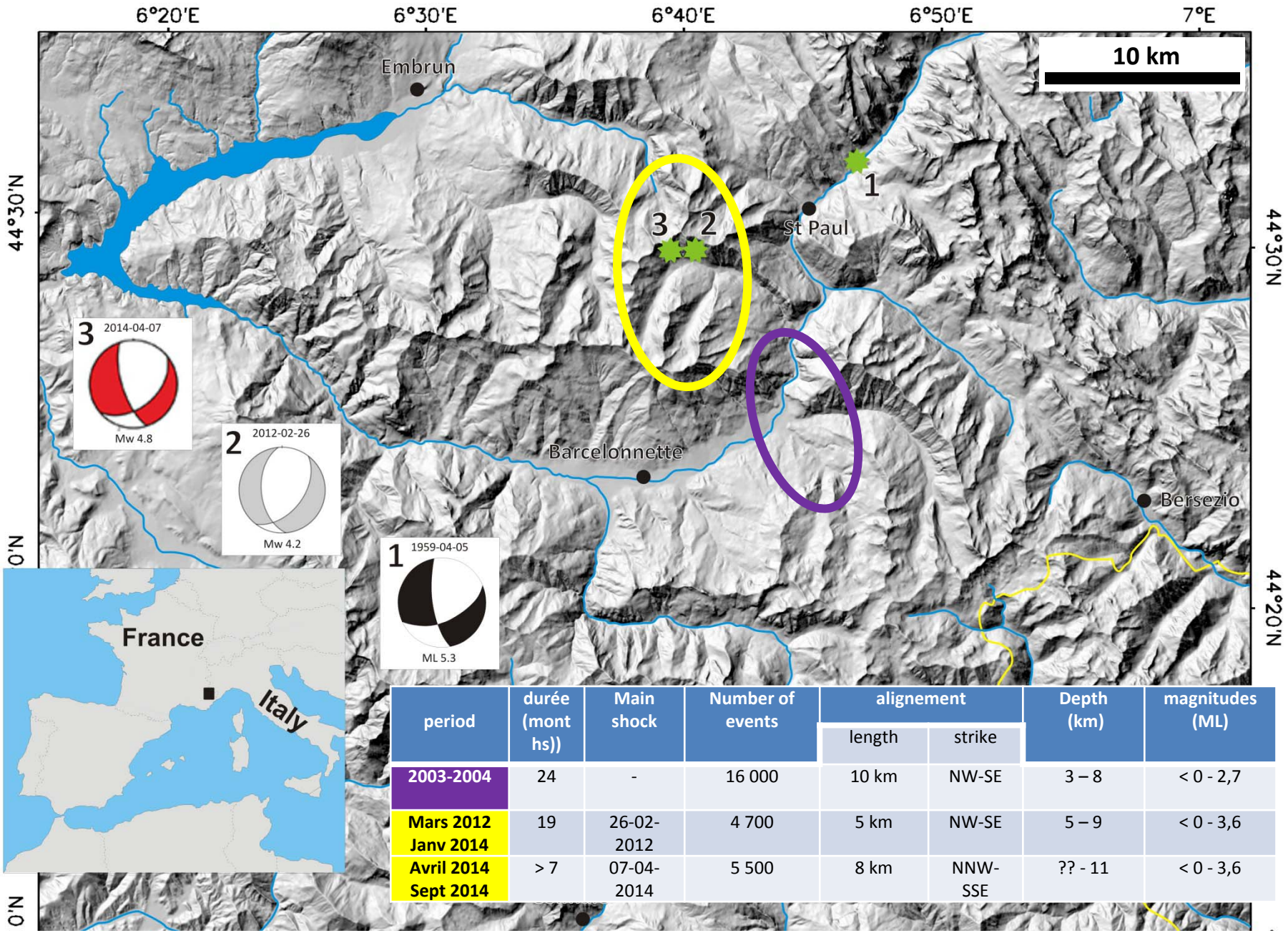


The organisation of DEFORM 2015 (which have really large means) decided to shift from theory to practice….

2 earthquakes of ML 3.0, at 5h39 UTC and 13 sec interval, ~10 km north of Barcelonnette.

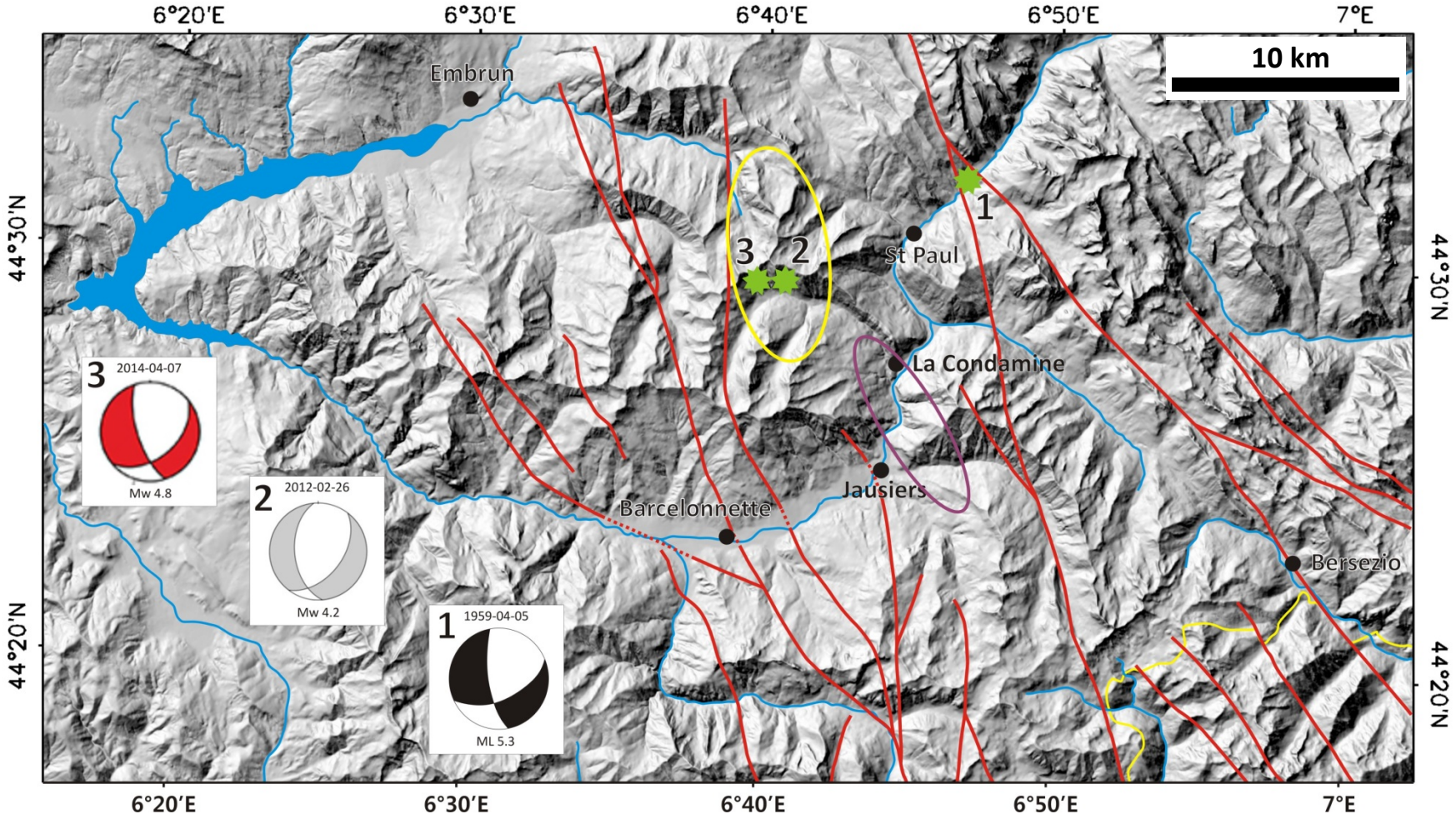
François Thouvenot, IsTerre
(for the picture but not the comment…)
http://sismalp.obs.ujf-grenoble.fr/

In bref…



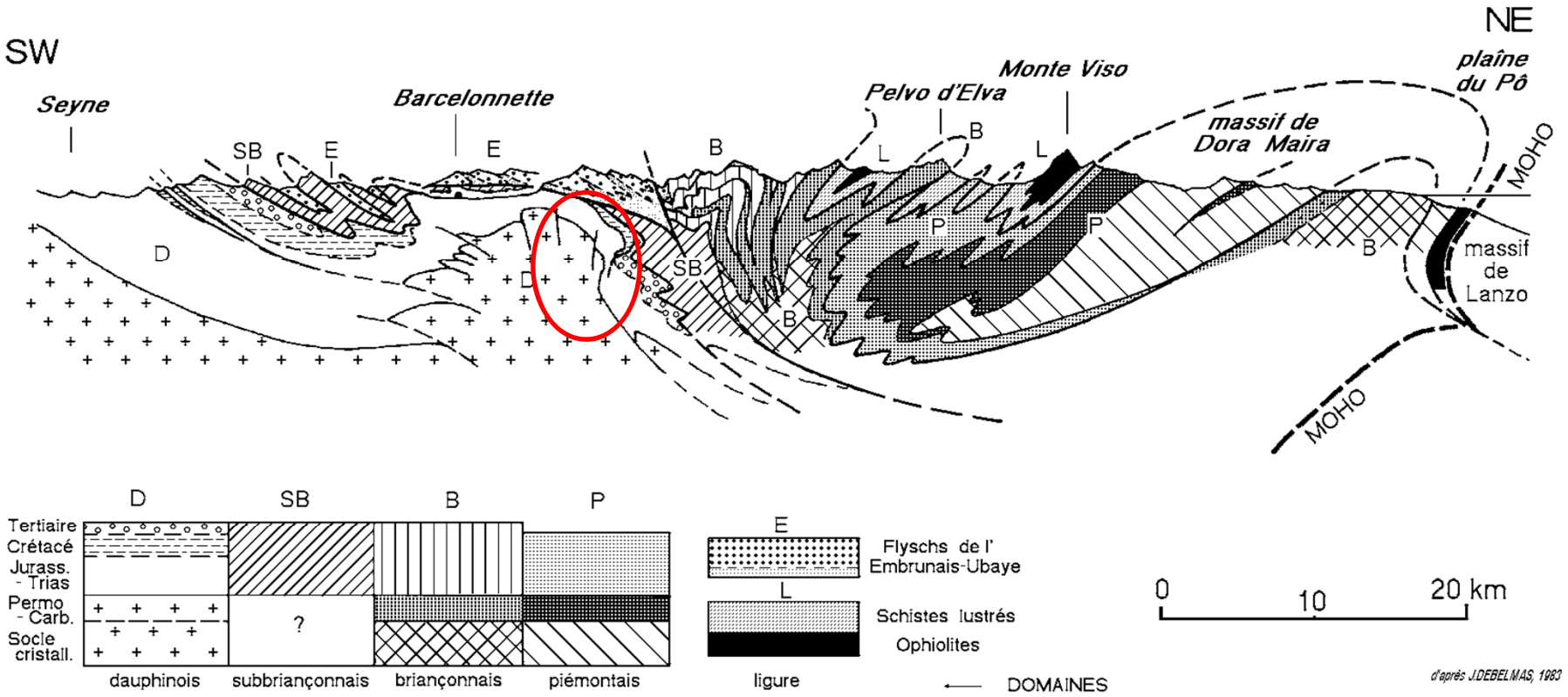
period	durée (months))	Main shock	Number of events	alignement		Depth (km)	magnitudes (ML)
				length	strike		
2003-2004	24	-	16 000	10 km	NW-SE	3 – 8	< 0 - 2,7
Mars 2012 Janv 2014	19	26-02-2012	4 700	5 km	NW-SE	5 – 9	< 0 - 3,6
Avril 2014 Sept 2014	> 7	07-04-2014	5 500	8 km	NNW-SSE	?? - 11	< 0 - 3,6

Taking into account the geometry of the swarms and the consistency of the faulting (focal mechanisms) of the main shocks, the activation of a fault, or a set of faults during these events and the possibility, for the future, to activate in only one largest event (Mw > 6) one of these faults is a crucial concern.
Then, is there some faults in this area ?

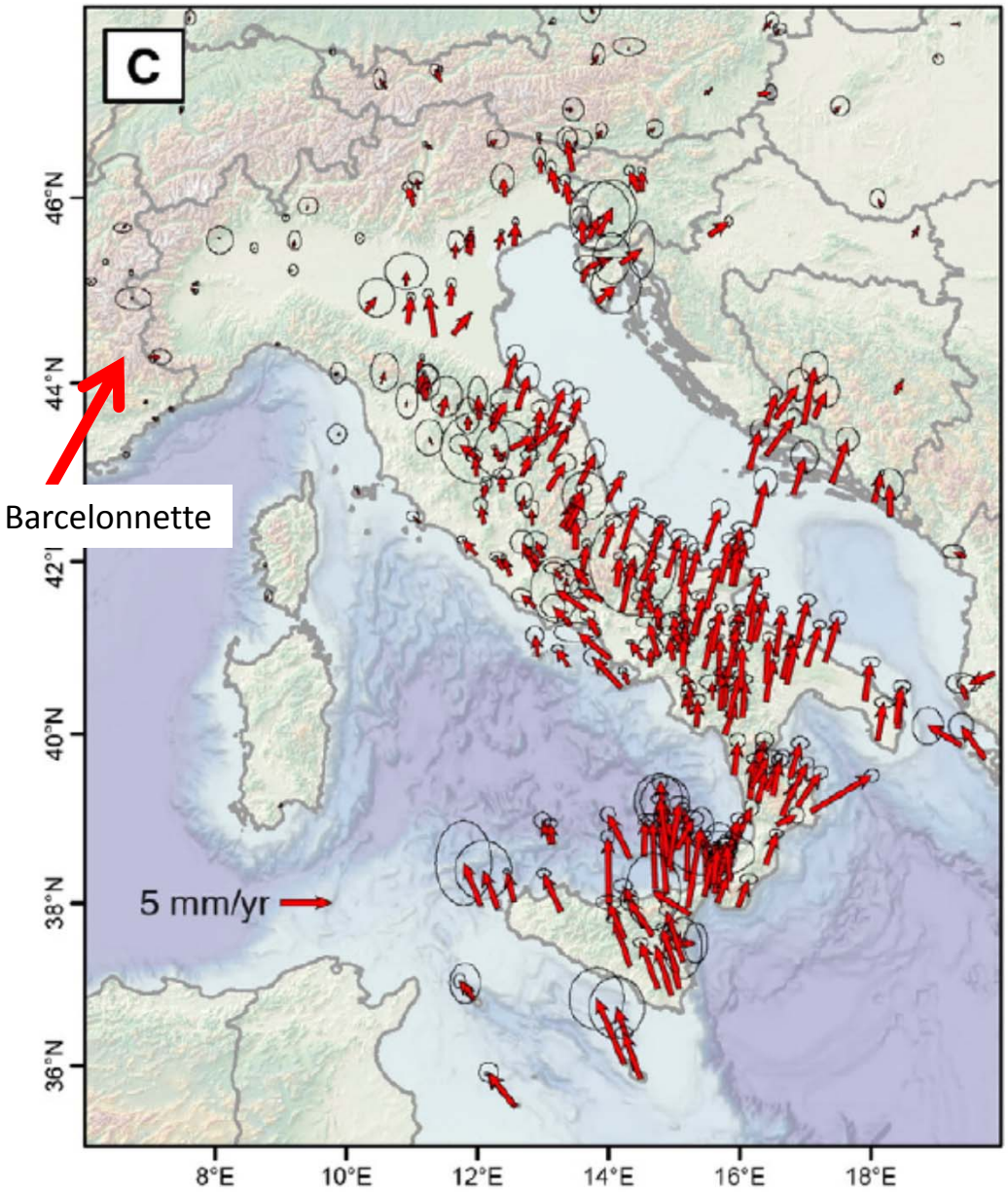


As in numerous continental areas, a lot of faults are inherited from previous deformation periods. In red are the faults mapped and related to late alpine deformation episode (the most recent one, from ~10 to 3 Myr). These dextral strike-slip faults show a strike consistent with the direction of the swarms and with the NNW-SSE nodal planes of the focal mechanisms.

Approximate location of the swarms in red on a NE-SW geological cross-section through the alpine structures.



What is loading the faults in the area ?



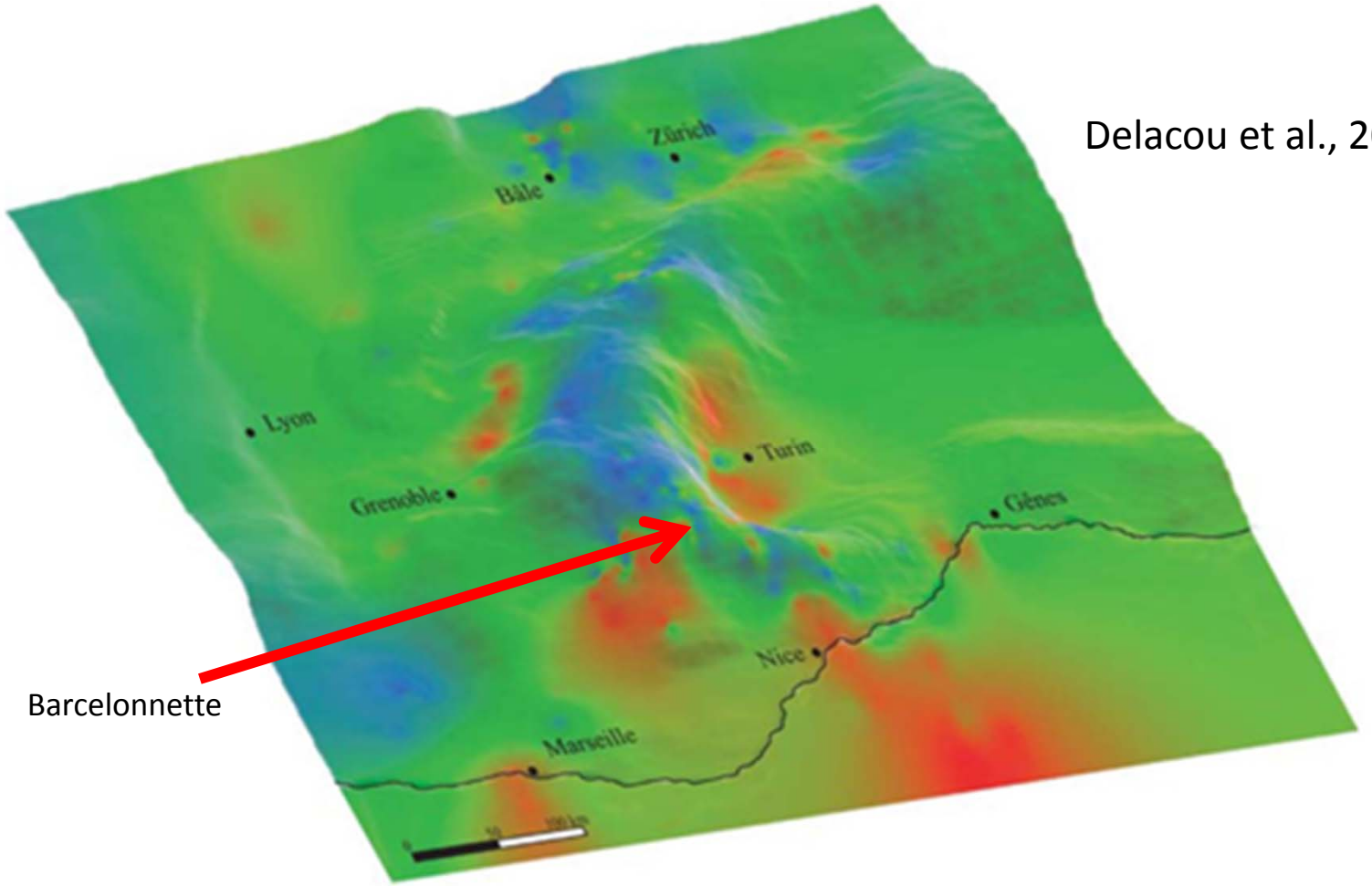
The tectonic loading of the faults could be due to the far field influence of the Nubia-Europe convergence or to the Adria microblock counter-clockwise rotation.

But, the northward convergence of Nubia is mainly accomodated along the Maghrebides (northern Africa) plate boundary and the rotation of the Adria microplate, with a euler pole close to the western Alps, produce an unsignificant horizontal motion in this area.

On this map is the results of cGPS measurements since 15 years. The horizontal motion in the Alps is close to zero.

Nocquet, 2012

What is loading the faults in the area ?

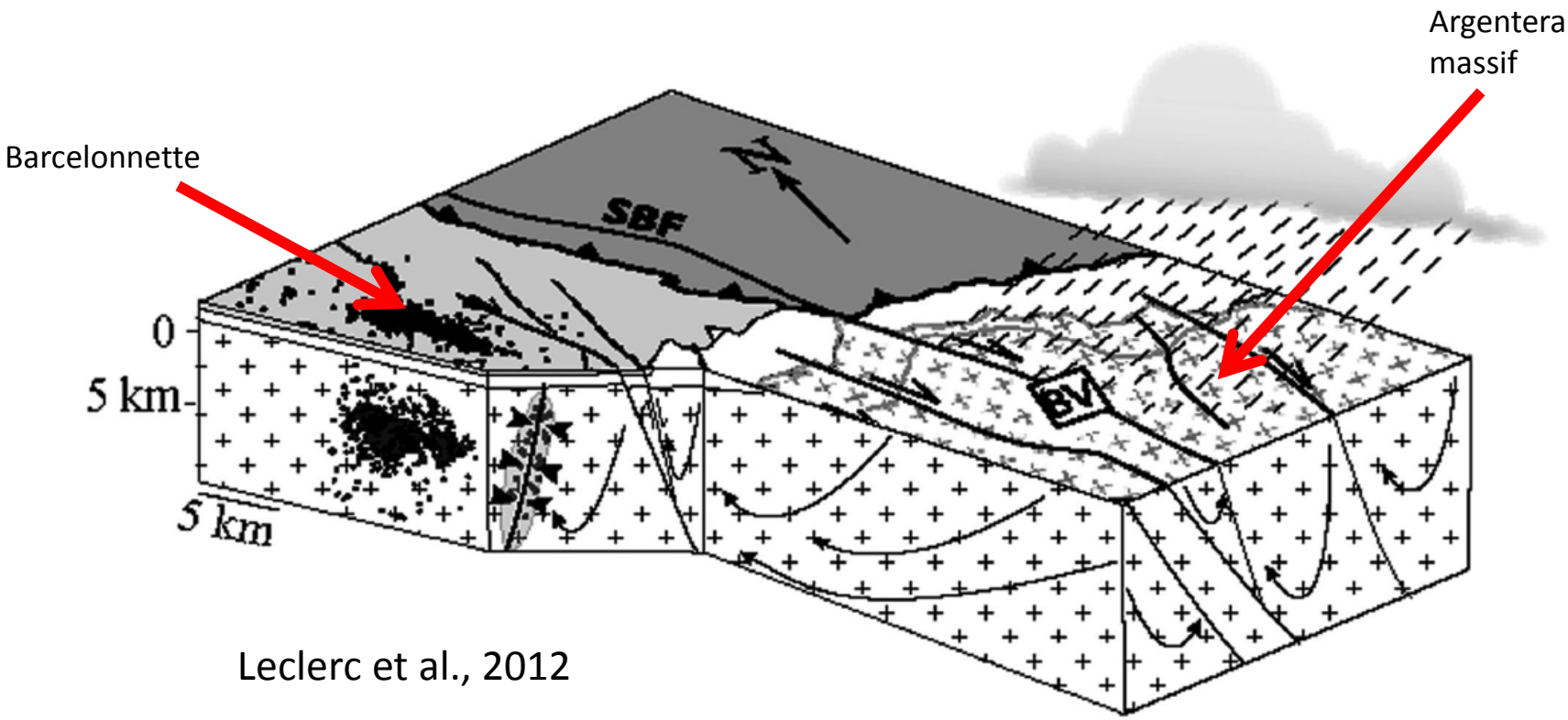


Delacou et al., 2004

The tectonic loading of the faults could be due to the gravitational forces resulting from the thickenning of the continental crust during the collision process.

This map at the scale of the western Alps (Italy, Switzerland and France) shows the distribution of the tectonic regimes determined from seismotectonic data. In blue are the extensional areas following mainly the high axe of the mountain belt (extensional axe is roughly perpendicular to the topgraphic culmination).

What is loading the faults in the area ?



Leclerc et al., 2012

The tectonic loading of the faults could be due to high-pressure fluid migrations.

The high-pressure fluids could be related to the impermeable sedimentary cover (in ligth grey on the picture) of the Barcelonnette area which stop the migration of meteoric fluids coming from the high elevation Argentera Massif along the high-porosity alpine faults zone.

What is loading the faults in the area ?

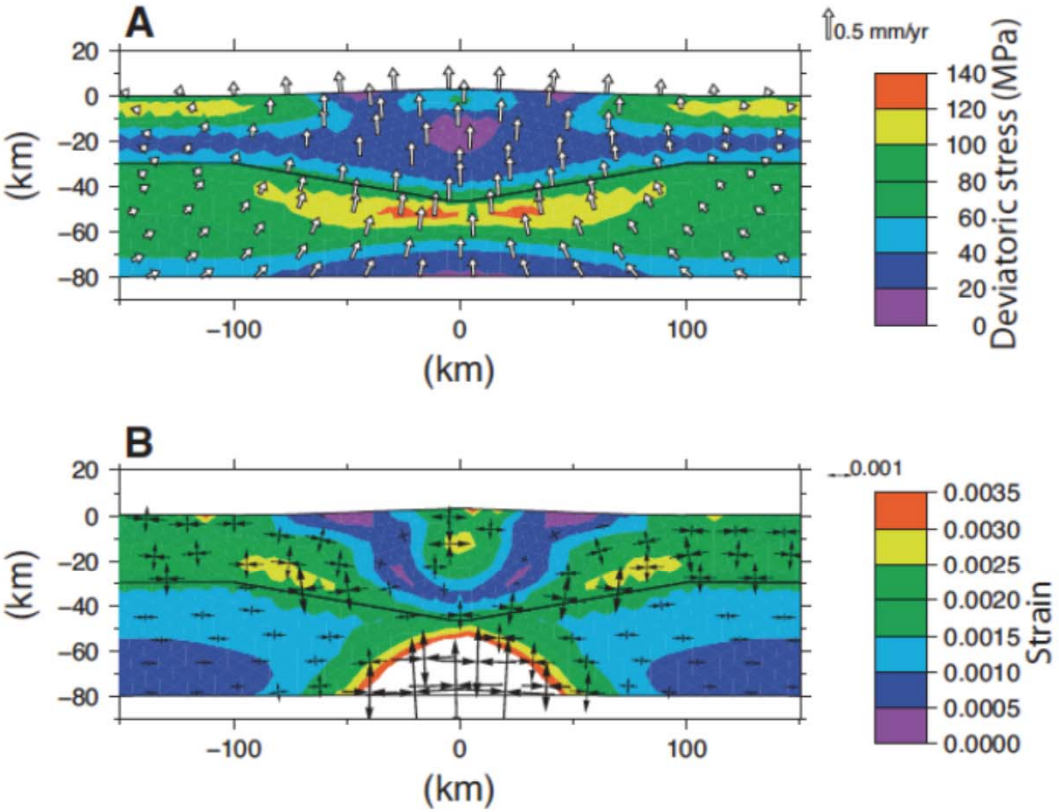


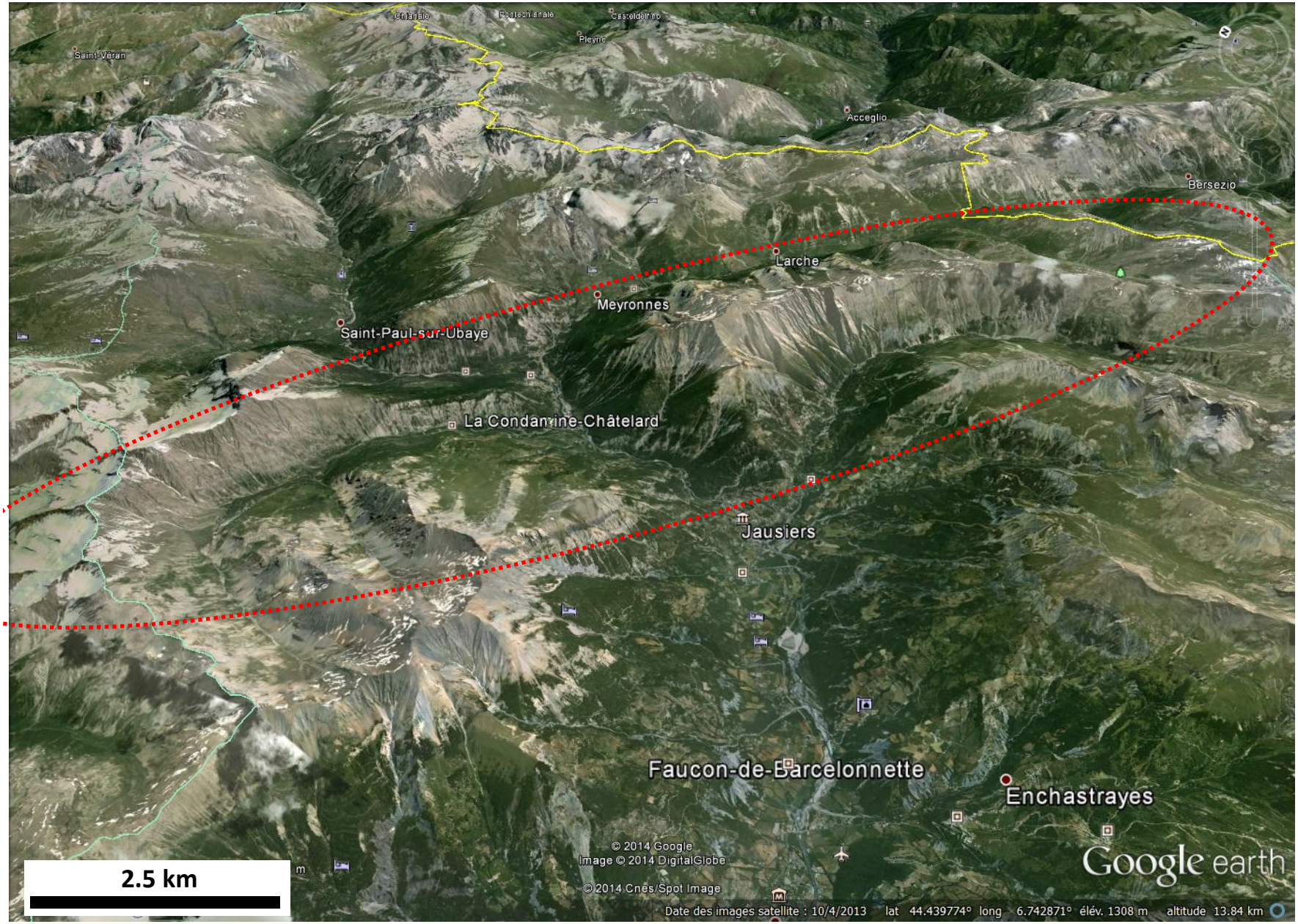
Figure 2: Erosion-induced stress and strain rate in mountain range. Results are shown for an erosion rate of 0.75 mm/yr and a convergence rate of 0.5 mm/yr) after 2 m.y. (steady state).
A: Velocity field and deviatoric stresses.
B: Strain tensor shows an extensionnal strain in the mountain core while the foreland area remains in compression (from Vernant et al. 2013).

Vernant et al., 2013

The tectonic loading of the faults could be due to the erosion-induced transfer of mass sediment from the high topography to the foreland.

The high erosion rate of the alpine relief modify the crustal stress and could load the faults without significant horizontal motion through the belt.

The question of the potential magnitude of future earthquakes introduce an other question : could we found some traces of ancient surface ruptures attesting for strong earthquake in this area ?
Can geologists say something from morphotectonics in such a very low deformation rate area ?



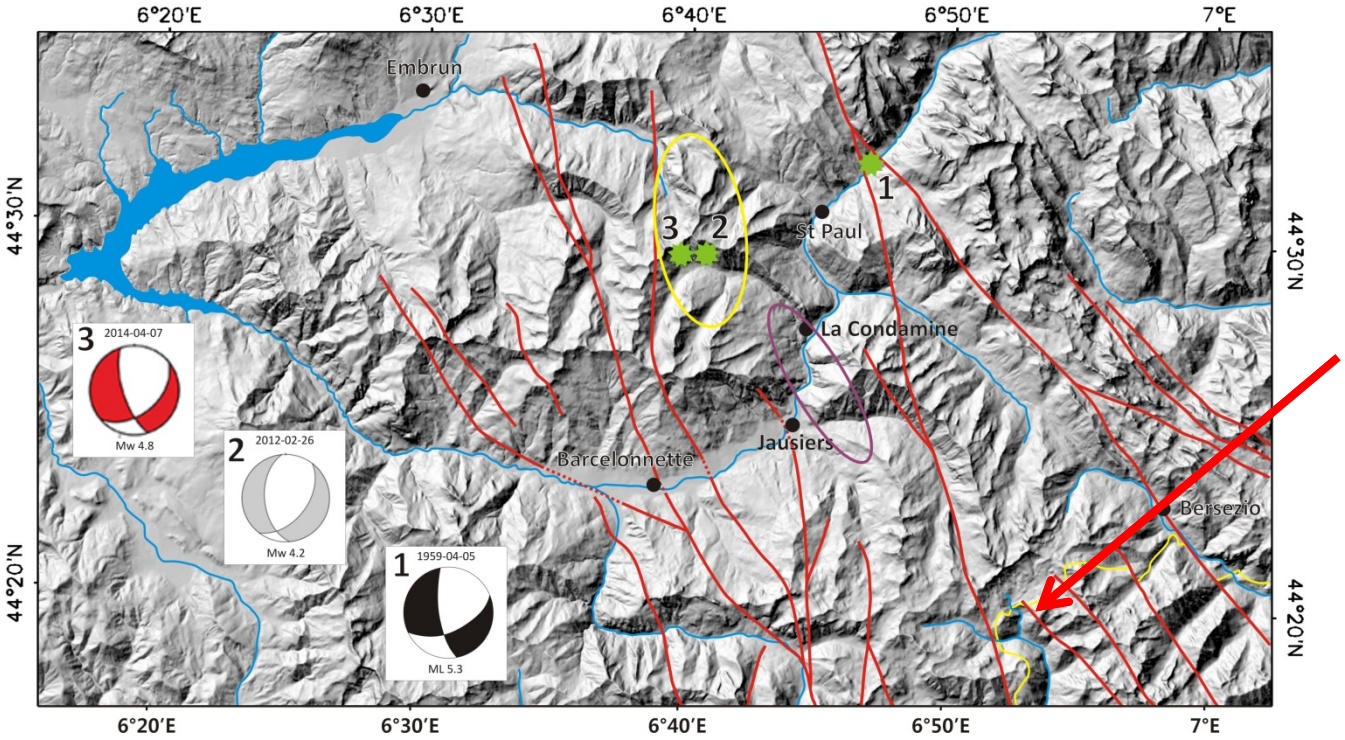
The red dotted line is the area of the swarms.

View to the East

This is an example of what could be discussed in the field !

Red circle : zoom on the next slide

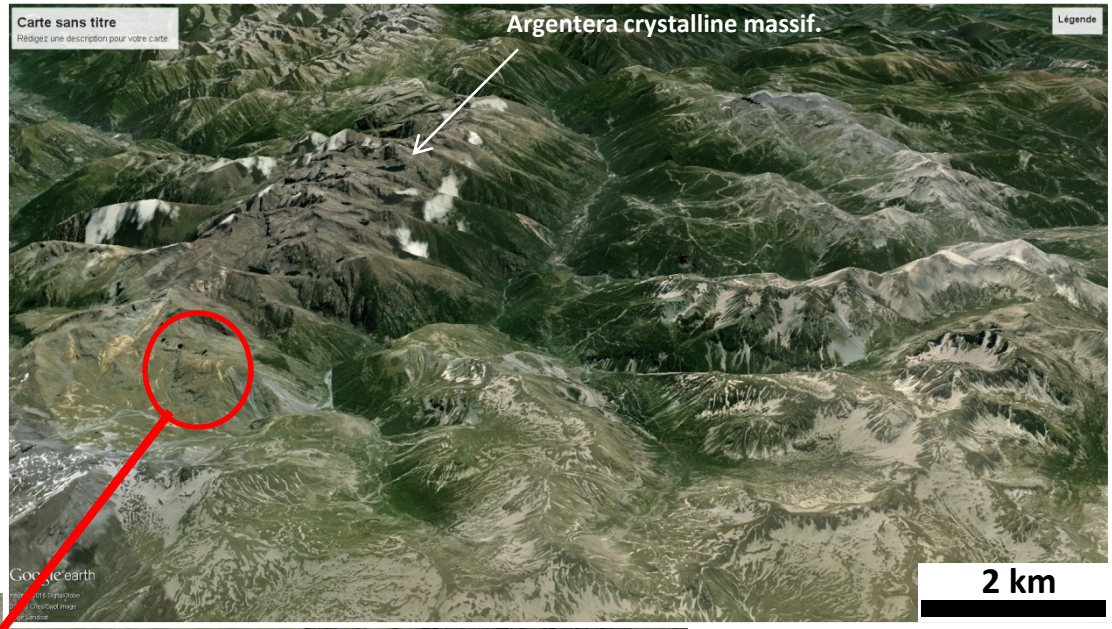
View to the South



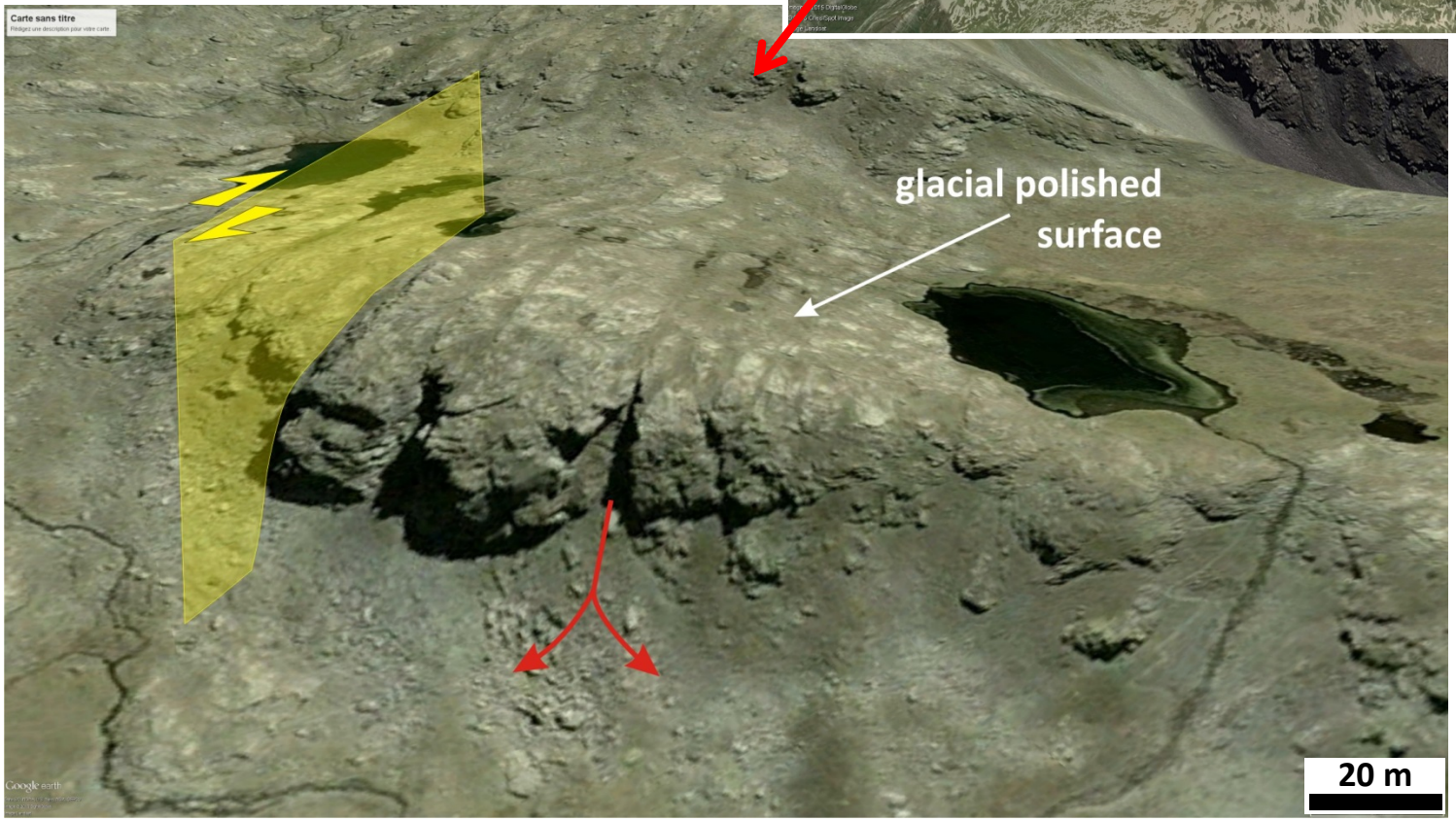
Is one of these large alpine faults, close to Barcelonnette, reactivated during the Holocene ?

(the one pointed by the red arrow)

South of Barcelonnette : view to the Argentera crystalline massif and the Tinée valley.



View to the South-East

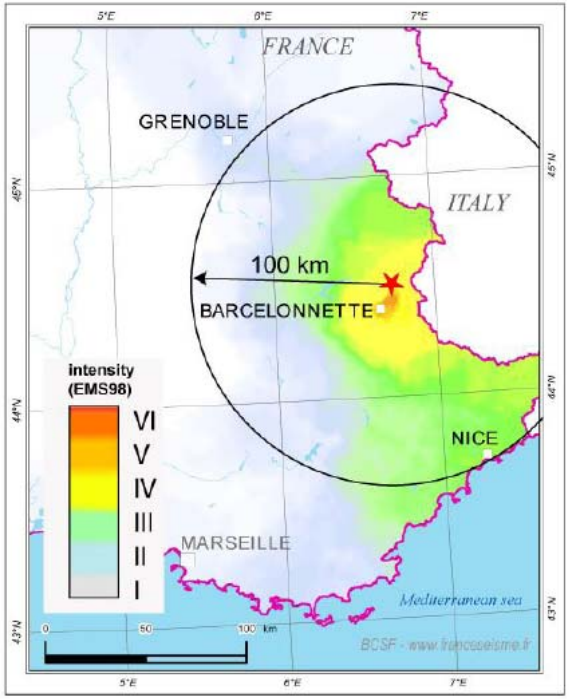


In the field, two interpretations :

- Yellow hypothesis : post-holocene dextral strike slip faulting (then measurements of offset, computation of magnitude, reccurence time….).

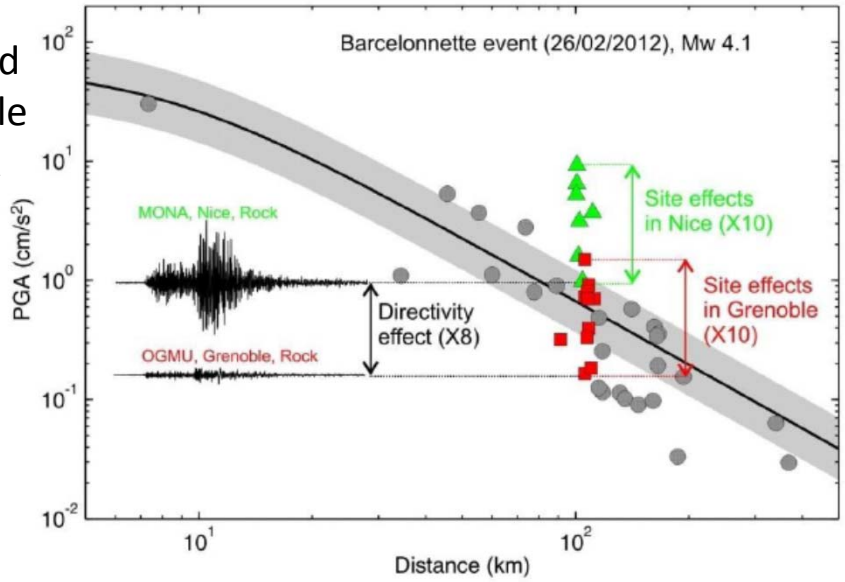
- Red hypothesis : erosion-exhumed fault plan of late alpine age, i.e. 5-3 Myr (nothing to do…).

Directivity effect for a small earthquake



Macroseismic intensities
2012-02-26 Mw 4.2

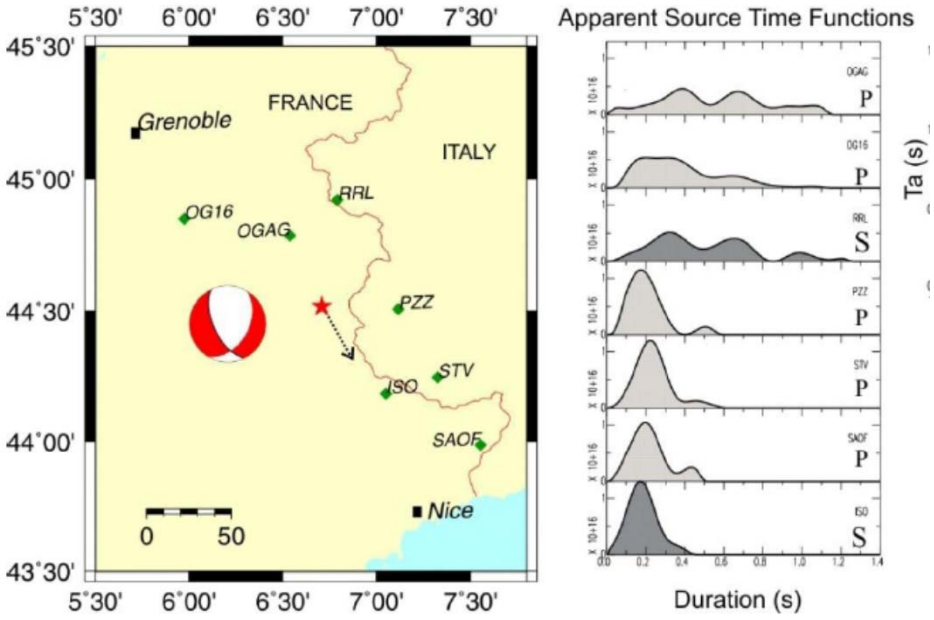
PGA values recorded at Nice and Grenoble versus PGME (black line)



During the 26 February 2012 earthquake, we observe a large difference of macroseismic intensities at 100 km of the epicenter (see the map in Nice and Grenoble).

A recent study (Courboulex et al. (2014) has shown that the PGA measured in Nice was 10 times higher than in Grenoble (the dispersion in each case is related to local site effects).

From the analysis of the apparent source time function, the authors conclude to a directivity effect of the rupture that propagates in a N155°E (direction of Nice) during 0.85 s.



Courboulex et al., 2014

Jenatton et al., 2007. The 16,000-event 2003-2004 earthquake swarm in Ubaye (French Alps). Journal of Geophysical Research, 112, B11304. doi:10.1029/2006JB004878

Nocquet, 2012. Present-day kinematics of the Mediterranean: a comprehensive overview of GPS results. Tectonophysics 579, 220–242. doi:10.1016/j.tecto.2012.03.037

Delacou et al., 2004. Present-day geodynamics in the bend of the western and central Alps as constrained by earthquake analysis. Geophysical Journal International 158, 753–774. doi:10.111/j.1365-246X.2004.02320.x

Leclerc et al., 2012. Reactivation of a strike-slip fault by fluid overpressuring in the southwestern French–Italian Alps. Geophysical Journal International, doi: 10.1111/j.1365-246X.2011.05345.x

Vernant et al, 2013. Erosion-induced isostatic rebound triggers extension in low convergent mountain ranges, Geology. 41, 467-470. doi: 10.1130/G33942

Courboulex et al., 2014. High-Frequency Directivity Effect for an Mw 4.1 Earthquake, Widely Felt by the Population in Southeastern France. Bulletin of the Seismological Society of America, 103, 6, 3347-3353. doi:10.1785/0120130073