A 3D broadband seismic array at LSBB

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Some users of the IRIS DMS may have noticed a new network acronym popping up on their screen: LSBB. This article provides an introduction to the most important features of this unique research facility.

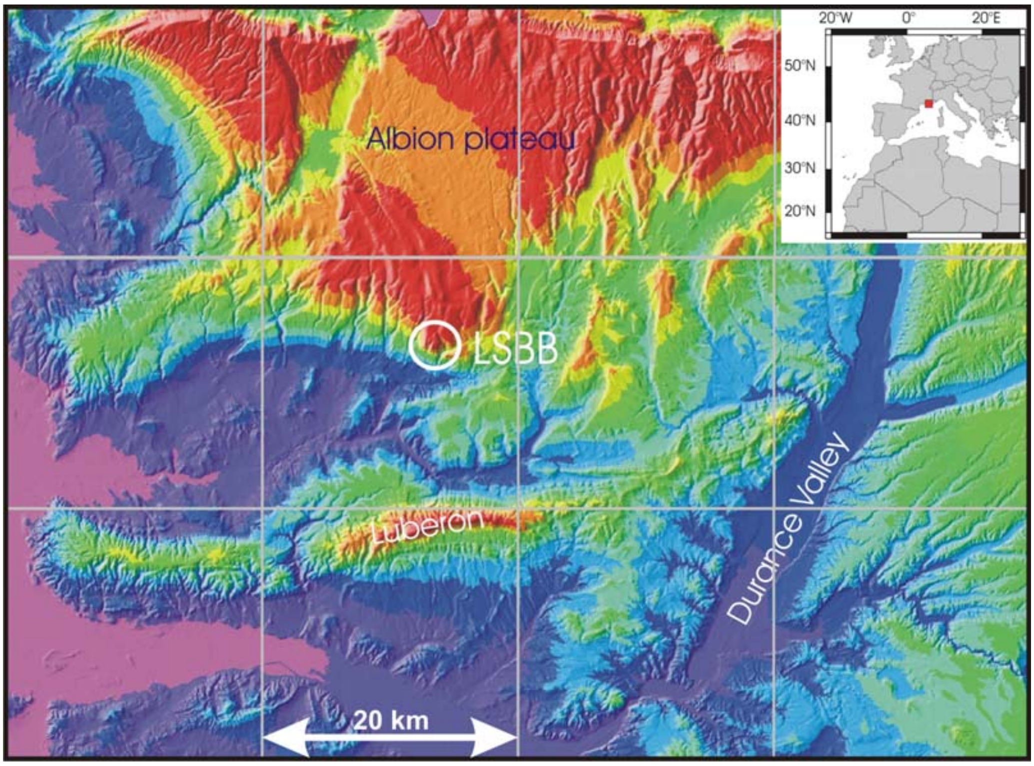

Fig. 1: Location of LSBB in the southern border of Fontaine-de-Vaucluse aquifer that flows from east to west below the Albion plateau.

The « Laboratoire Souterrain à Bas Bruit » (LSBB or « Underground Low-noise Laboratory ») in Rustrel, southern France (Fig. 1), a former command post for the nuclear forces of the French army, was designated in 2009 as a French National Instrumented Infrastructure by the Centre National de la Recherche Scientifique (CNRS), and dedicated to inter-Disciplinary Underground Science and Technology (*i*-DUST). It is currently used by more than thirty research groups to study topics ranging from finding the missing mass in the universe to studying the subsurface storage of CO_2 and the aquifer management of water resources and reserves. The underground galleries and the surrounding carbonate rock formations have been mapped by geological and geophysical imaging studies. The facility is horizontally accessible via a 3.7 km long tunnel with an L-shape (Fig. 2). The deepest vault is 518 m below the surface (□1500-meter water equivalent, m.w.e.). The laboratory spans a surface area of almost 100 acres, in an area named « la Grande Montagne ». All galleries and vaults have a power supply, phone, GPS time, and internet capability with fiber optic communication cables, and are connected to two huts on the surface.

La Grande Montagne shields instruments from many noise sources and the LSBB is located within the regional natural park of the Luberon, with few anthropogenic perturbations, centrally positioned at known distances away from large seismogenic faults of Provence (Baroux, 2003). This quiet area allows *in situ* access to the carbonate reservoir (Jurgawczynski, 2007) and *in situ* survey of hydraulic flows across the unsaturated porous and fractured zone, which is below the near-surface weathered zone and above the saturated zone of the Fontaine-de-Vaucluse aquifer (Garry et al., 2008).

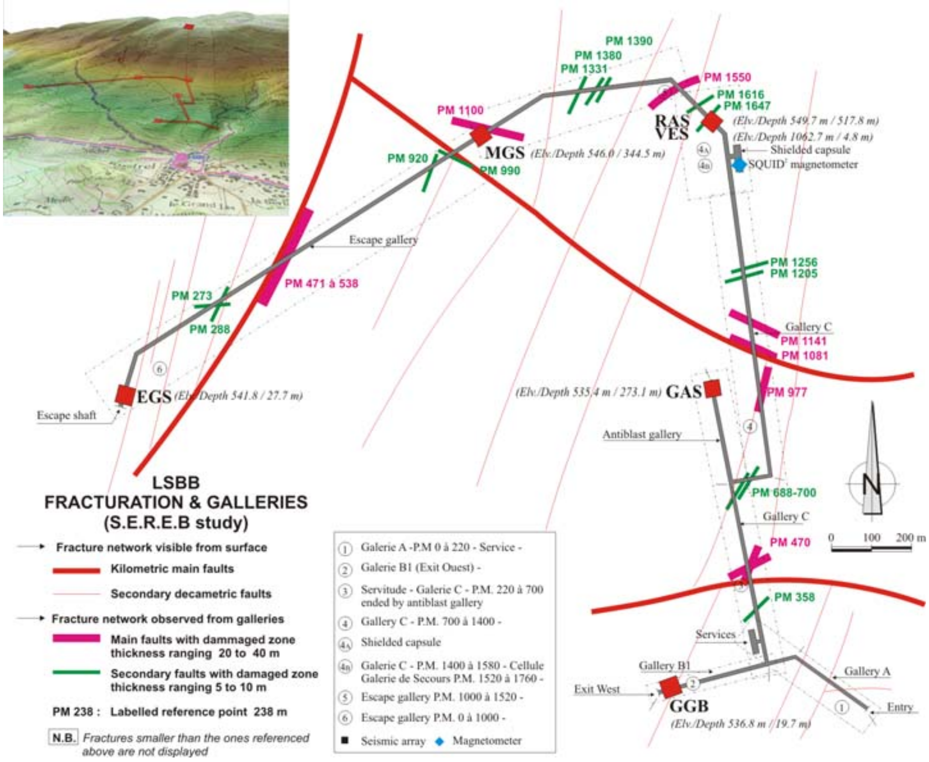

Fig. 2: Map of galleries and positions of seismometers. The upper left inset show schematically the orientation of the galleries below the mountain together with the sensor locations and the vertical borehole that joins facility to the surface topography.

The black box symbols in Fig. 2 show the locations of the six broadband STS2 3-components seismometers recorded with Agecodagis digitizers (http://www.agecodagis.com) with 125 samples per second. The 3D array contains one near-surface station together with the five deep stations. One sensor station labeled as VES is located near the top of the mountain at an elevation of 1062 m (and 5 m below the surface). The other five sensor stations are located at approximately the same elevation, between 535 m and 549 m (the reference. geoïd). The depth of these five stations at the LSBB tunnel level with overburden coverage below the surface topography varies from 20 m for Station GGB (near the LSBB entrance) to 518 m for Station RAS, the deepest sensor, at the center of LSBB. The deepest Station RAS also has a CMG5 accelerometer. The prime motivations for installing this array are (i) to monitor the seismic noise variations at the LSBB in order to discriminate between various noise sources that may perturb all other experiments running in LSBB (e.g., change in water saturation, hence wave velocities); (ii) to determine the azimuth and apparent velocities of high-frequency body waves, given the very low noise level and the horizontal extension of about 1.5 km; and (iii) to allow for a comparison at different scales between solid block rotations of the surrounding mountain derived from the 3D array with direct tilt measurements conducted inside the mountain. The establishment of an LSBB seismic array facilitates many other observations, including the studies of magnetometry and water chemistry, as well as the study of poroelastic coupled-processes dynamics induced by seismic waves that propagate within the medium (Cappa et al., 2006).

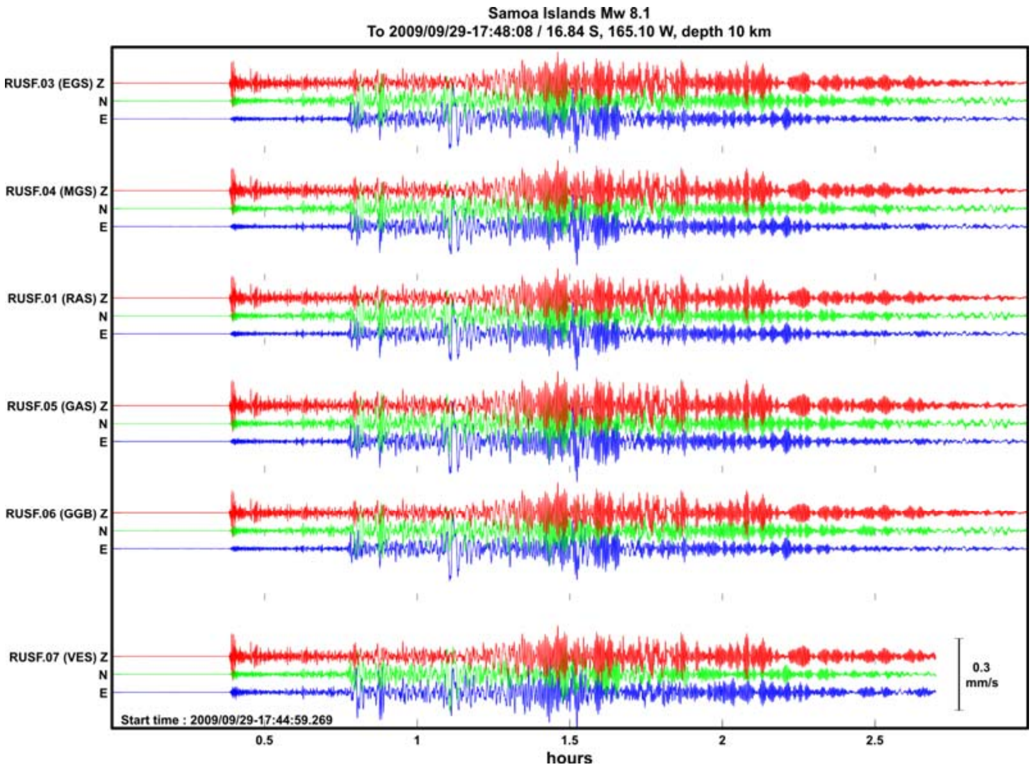

Fig.3: Example of data recorded for the Mw8.1 Samoa event occurred in september 2009, showing the great coherency for all components and waveform effect on free surface sensor.

The facility is open to European and international researchers. Collaboration agreements are established with LBNL, USA, and UBC, Canada, in order to initiate international, interdisciplinary development. LSBB and LBNL jointly propose and organize the AGU session NH17 on “Seismic Coupling from Underground, Surface, to Ionosphere” in 2009, the 3rd International *i*-DUST Conference in 2010, and an Underground Research Laboratory Workshop associated with the 12th ISRM Congress on Rock Mechanics in 2011. LSBB welcomes multidisciplinary programs that share knowledge and know-how that promotes innovation (e.g., Projects HPPPCO2, MAXWELL, LINES from the French National Research Agency). The data from all instruments in the LSBB are distributed online—see http://lsbb.oca.eu. In particular, the data recorded by the 3D broadband seismic array, available at http://websismo.unice.fr, are fed in real time via SeedLink to the European Union seismic network (ORFEUS, http://www.orfeus-eu.org) and are now also available via IRIS, http://www.iris.washington.edu. Sensors EGS, MGS, RAS, GAS, GGB and VES depicted in Fig. 3 correspond to the streams RUSF_03, 04, 01, 05, 06, and 07 respectively. Data are also available by autoDRM (Kradolfer, 1993, 1996) using autodrm@geoazur.unice.fr, and via the Fosfore portal http://www.fosfore.ipgp.fr by NetDC using netdc@ipgp.jussieu.fr or netdc@geoazur.unice.fr.

The LSBB also houses a low ambient magnetic noise (SQUID)[2] 3-axis magnetometer located within the deepest shielded cage (see the blue box symbol in Fig. 1b). This 28 m long, 8 m diameter vault acts as a low-pass filter that shields the Earth's magnetic field, allowing us to observe the Earth's magnetic field variations for frequencies below 40 Hz (Henry et al., 2008). On the high-frequency end, the total magnetic field strength is detected to a level lower than 2 $fT/\sqrt{Hz}$, which is at the limit of instrumental magnetic observability (Bordes et al., 2008). In addition to the seismic array and the magnetic sensor, tiltmeters, radiation sensors, groundwater pressure, and chemistry monitoring devices are installed to characterize the environment along the tunnel that allows interdisciplinary studies including seismicity, electromagnetism, ionosphere/magnetosphere physics, etc. (Gaffet et al., 2003; Waysand et al., 2009; Marfaing et al., 2009).

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