Connecting seismicity, gravity-driven erosion and deposition at submarine normal faults: Insights from mapping of the 2004 Mw 6.3 Les Saintes earthquake rupture (French Antilles)

Javier Escartin¹, Jeremy Billant², Frédérique Leclerc², Jean-Arthur Olive¹, Klemen Istenic³, Nuno Gracias³, Rafael Garcia³, Aurelien Arnaubec⁴, Christine Deplus⁵, Nathalie Feuillet⁵, and the SUBSAINTES Science Party

¹Laboratoire de Géologie, Ecole Normale Supérieure (ENS), Paris, France
²GeoAzur, Univ. Cote d'Azur, Sophia-Antipolis, France
³Girona Underwater Vision and Robotics, Univ. Girona, Spain
⁴Unité de Systèmes Sous-marins, IFREMER, Toulon, France
⁵Institut de Physique du Globe de Paris, Paris, France

*A full list of authors appears at the end of the abstract

During the ODEMAR 2013 and SUBSAINTES 2017 cruises we mapped the full extent of the seafloor rupture associated with the 2004 Mw 6.3 Les Saintes extensional earthquake. Near-bottom bathymetry acquired both with ROVs and AUVs along the Roseau Fault reveal a normal fault scarp developing in an extensional graben within the Caribbean volcanic arc, between the islands of Guadeloupe and Dominica. Optical inspection during ROV dives along the scarp's base, where fault mirrors are well-preserved, allowed us to identify and characterize the coseismic fault rupture, and measure the coseismic displacements using both laser calipers and measurements performed on video-derived, textured 3D models, with accuracies better than 1 cm.

The 2004 rupture extends ~20 km along the Roseau Fault, with a vertical displacement exceeding 2.5 m at its center, and tapering towards its ends. Local variations in apparent fault slip within a single 3D model (fault lengths of ~10 to 300 m) document local deposition of gravity debris cones at the base of the scarp, extending laterally between a few to tens of m, and covering the coseismic markers. Gullies eroding the footwall and depositing debris cones on the hanging wall do not show any significant displacement. Fault scarps on either side of the gully mouth instead record significant displacements, suggesting that either erosion or deposition along the gully bottom efficiently obliterated markers of coseismic deformation.

We inspected all overlapping seafloor imagery acquired in December 2013 and April 2017, >10 years after the 2004 Les Saintes earthquake, extending laterally over >3 km of the Roseau Fault rupture. Neither the bed of gullies crossing the rupture, nor the debris and rubble at the base of
the fault scarp show any noticeable seafloor change indicating mass wasting and transport, and only changes in mobile sediment (e.g., ripples) can be detected between both image sets. We identified a single area, ~2m wide, with apparent deposition of pebbles during these 3.25 years period, and associated with a local mass-wasting event.

These observations point towards a systematic triggering of mass-wasting during seismic events, with deposition of rubble and rocks both at dejection cones at the mouth of gullies, or at the base of fault scarp sections displaying fault mirrors, covering or obliterating the coseismic markers. Therefore, long-term erosion and deposition processes here are gravity-driven and triggered by the history and magnitude of seismic events. Similar seismic controls may enable denudation of exposed oceanic lithosphere at fault scarps developing along and flanking mid-ocean ridges.