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Seafloor rupture of a normal fault: geometry, displacement, and links between erosion/sedimentation and seismicity

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The Mw 6.3 2004 Les Saintes earthquake ruptured the Roseau normal fault off Les Saintes (French Antilles). A 2013 preliminary survey (ODEMAR cruise) documented at one site 0.9 m of vertical coseismic displacement and near-fault hangingwall cracking. During the 2017 SUBSAINTES cruise an AUV acquired microbathymetry and an ROV observations and 3D video reconstructions with image texture.

First, we have fully mapped fully for the first time a submarine normal fault rupture, documenting recent deformation structures along ∼15-20 km of the Roseau fault. Rupture indicators include well-preserved sub-vertical fault planes (primarily at the center of the rupture), cracks and fissures through sediment and rubble (more abundant at the rupture tips), and near-fault damage extending up to ∼200 m off-fault locally.

3D terrain models of the rupture documented clearly the coseismic rupture, owing to a lack of manganese crust and weathering patina on the coseismically exposed ruptures. The coseismic ribbon can be followed continuously along >100 m at the base of fault planes in several 3D models. We document a maximum coseismic vertical displacement of 2.5 at the rupture centre and tapering away from it This displacement varies at scales of ∼200-500 m as observed in subaerial coseismic ruptures, owing to heterogeneities in fault slip and strain localization.

Moreover, several 3D models show changes in colour and/or texture of the fault scarp, both above and within the 2004 coseismic slip ribbon. Based on the similarity in geometry between these older ribbons and the 2004 one, we conclude that records of prior seismic events may be preserved locally.

Second, the acquired data suggests a close correlation between seismicity and erosion/sedimentation processes. The Roseau fault scarp is incised by gullies with dejection cones at their mouth. The 2004 coseismic ribbon at fault oucrops adjacent to these cones taper towards gullies over distances of 10's of m, while no sinificant fault displacement is observed at gullie axes. Furthermore, detailed comparison of seafloor photomosaics between 2017 and 2013 acquired over gullies, dejection cones, and the base of the fault scarp, reveal no apparent sedimentation nor material mobilization. This suggests that reactivation of cones in 2004 was likely coseismic, locally covering the coseismic rupture, and that inter-seismic erosion processes are slow.

Fault scarp morphology, incised by gullies and associated erosional basins, informs on the long-term erosion/deformation processes. The apparent volume of dejection cones is smaller than the eroded volume of the basins, suggesting partial burial of eroded material. On-going dating of footwall volcanic units, together with models of erosion/sedimentation, may provide constraints on the links between tectonic deformation and gravity-driven erosion at this and other submarine environments.

Finally, this study demonstrates that detailed submarine field work using deep-sea vehicles can be conducted at spatial scales and resolutions similar to those on-land. It also opens the door to a systematic and detailed study of submarine ruptures elsewhere; two-thirds of the Earth's seismicity occurs off-shore and remains unstudied, and tectonic interactions with erosion and sedimentation may play a major albeit unconstrained role in submarine landscape evolution.