California, USA, benzion@usc.edu; VERNON, F. L., University of California, San Diego, California, USA, flvernon@ucsd.edu

We present key space-time-magnitude patterns of microseismicity observed in an updated catalog for the San Jacinto Fault Zone (SJFZ)—the most seismically active region in Southern California—during the period 2008-2022. We deploy an automated procedure to process raw waveform data from five seismic networks and capture a more complete representation of the space-time-magnitude distribution of events in the SJFZ than the standard catalog for the region. Seismicity patterns in our new catalog delineate the geometry of the locked region of the fault and the brittle-to-ductile transition zone (BDTZ)—features bearing important implications on the maximum potential magnitude of future ruptures in the area. Spatiotemporally diffuse seismicity characterizes semi-brittle deformation in the BDTZ, in contradistinction to the tightly clustered nature of seismicity in the overlying brittle crust. We observe transient clustering of seismicity in the BDTZ following some, but not all, moderate-sized events (M>4.5) in the region. Our high-definition catalog also helps constrain complex internal geometry of fault zone structures such as (1) anastamosing braids of deep seismicity in the Hot Springs Area; (2) conjugate networks of shallow fractures flanking the core fault zone; (3) the extent of the Anza Seismic Gap; and (4) branching structures in the Trifurcation Region. We will present an overview of these features and plans to further improve the SJFZ catalog using new tools.

Structural Control on the Distribution of Earthquake Clusters Along the Northern Ecuadorian Margin

PONCE, G., Lehigh University, Pennsylvania, USA, mgp222@lehigh.edu; MELTZER, A., Lehigh University, Pennsylvania, USA, ameltzer@lehigh.edu; BECK, S., University of Arizona, Arizona, USA, slbeck@arizona.edu; RUIZ, M., Escuela Politécnica Nacional, Quito, Ecuador, mruiz@igepn.edu.ec; HERNANDEZ, S., Escuela Politécnica Nacional, Quito, Ecuador, shernandez@igepn.edu.ec; ERICKSEN, B., University of Arizona, Arizona, USA, bericksen@arizona.edu; GALVE, A., Université Côte d'Azur, Institut de Recherche pour le Développement, Centre National de la Recherche Scientifique, Observatoire de la Côte d'azur, Géoazur, Valbonne, France, galve@geoazur.unice.fr; RIETBROCK, A., Karlsruhe Institute of Technology, Karlsruhe, Germany, rietbrock@kit.edu; AGURTO-DETZEL, H., Karlsruhe Institute of Technology, Karlsruhe, Germany, hans.detzel@kit.edu; RODRIGUEZ, E., University of Arizona, Arizona, USA, rodrigueze@arizona.edu; SEGOVIA, M., Escuela Politécnica Nacional, Quito, Ecuador, msegovia@igepn.edu.ec; RAMOS, C., Escuela Politécnica Nacional, Quito, Ecuador, cramos@igepn.edu.ec

High resolution studies reveal the complexity and diversity of structure and physical properties in subduction zones. Studies to date, particularly after the 2016 Mw 7.8 Pedernales megathrust rupture, indicate earthquake clustering and slip behaviors that host frequent seismic swarms and repeating earthquakes along the Ecuador subduction margin. Structure in the subducting and upper plate and frequent aseismic release of accumulated stress seem to play an important role in megathrust rupture. The HIPER Project (High Resolution Imaging of the Pedernales Earthquake Rupture Zone) is a large multidisciplinary international collaboration to image the plate interface in the megathrust region. As part of the Project, temporary deployments recorded passive and active sources over two years to study lateral heterogeneity downdip and along strike in the forearc. The passive recordings included the deployment of 59 broadband stations across the forearc from the coast to the foothills of the Andes. Two linear arrays of nodes spaced about 1 km apart during 1-month: 158 nodes along strike near the coast crossing the Punta Galera, Cojimíes-Atacames and Jama earthquake clusters and 141 nodes along a dip direction across the forearc above the subducting Carnegie Ridge. In 2022, active sources from a dense 2-D grid of marine airgun were recorded by 483 nodes deployed near the coast. This provides an exceptional opportunity for onshore/offshore multiscale 3D imaging of the northern Ecuador. Here we focus on the margin from Punta Galera to Jama. Using the dense deployments, we present the spatio-temporal distribution of seismicity during this period in context of long-term observations. The ultimate goal of these deployments is to obtain precise locations of seismic sources along the northern margin of the subduction zone to better characterize deformation and its potential connection to rheology and structures that appear in part to control megathrust rupture and earthquake clusters.

Linking Fault Roughness at Seismogenic Depths to Earthquake Behavior

PAGE, M., U.S. Geological Survey, California, USA, pagem@caltech.edu; COCHRAN, E. S., U.S. Geological Survey, California, USA, ecochran@usgs.gov; VAN DER ELST, N., U.S. Geological Survey, California, USA, nvanderelst@usgs.gov; ROSS, Z. E., California Institute of Technology, California, USA, zross@gps.caltech.edu; TRUGMAN, D. T., University of Nevada, Nevada, USA, dtrugman@unr.edu

Fault geometry affects the initiation, propagation, and cessation of earthquake rupture, as well as, potentially, the statistical behavior of earthquake sequences. We analyze 18,250 earthquakes comprising the 2016-2019 Cahuilla, California swarm and, for the first time, use high-resolution earthquake locations to map, in detail, the roughness across an active fault surface at depth. We find that the fault is 50% rougher in the slip-perpendicular direction than parallel to slip. Roughness estimates are spatially variable, and fluctuate by a factor of 8 over length scales of 1 km. We observe that the largest earthquake (M4.4) occurs where there is significant fault complexity and the highest measured roughness. We also find that b-values are weakly positively correlated with fault roughness. Following the largest earthquake, we observe a distinct population of earthquakes with comparatively low b-values occurring in an area of high roughness values within the rupture area of the M4.4 earthquake. Finally, we measure roughness at multiple scales and find that the fault is self-affine with a Hurst exponent of 0.52, consistent with a Brownian surface.

Micro-Seismicity Clustering, Aftershock Decay and b-Values During Laboratory Fracture and Stick-Slip Experiments

GOEBEL, T. H. W., University of Memphis, Tennessee, USA, thgoebel@memphis.edu; KWIATEK, G., GFZ Potsdam, Potsdam, Germany, kwiatek@gfz-potsdam.de; DAVIDSEN, J., University of Calgary, Calgary, Canada, jdavidse@ucalgary.ca; THAPA, N., University of Memphis, Tennessee, USA, nthapa@memphis.edu; DRESEN, G., GFZ Potsdam, Potsdam, Germany, dre@gfz-potsdam.de

Earthquakes rarely occur in isolation but rather as sequences of events, clustered in space and time. We study seismic event clustering in controlled laboratory experiments where fault zone properties and stress can directly be monitored. We employ recently-developed statistical methods (e.g., nearest-neighbor clustering, R-statistic, Bi-statistic) to resolve seismic event interactions in series of experiments on in-tact and faulted Westerly granite samples. The samples exhibit different heterogeneity and roughness which strongly impact seismicity clustering.

Our result show that heterogeneity in intact-samples promotes spatial clustering of seismic events albeit without temporal (Omori-type) correlations. Aftershock-like clustering is absent even during fracture nucleation and propagation close to peak stress. Aftershock-like triggering occurs during stable sliding on freshly formed fractures and in the presence of large-scale stress heterogeneity. The detected aftershocks in these cases can be described by standard seismological relationships such as a modified Omori-Utsu relation and its associated inter-event time distribution and productivity relation. Similarly, stick-slip on rough faults is associated with notable spatial-temporal seismicity clustering and Omori-decay mirroring natural seismicity statistics. Homogenous, planar surfaces, on the other hand, produce few aftershocks after unstable slip. Fault roughness also governs b-values and focal mechanisms variability. Rough faults lead to more heterogeneous focal mechanisms, spatially distributed seismicity and high b-values. The variability in focal mechanisms can be explained by heterogeneous, underlying stress fields which limit rupture size and promote high energy release within aftershock sequences. We conclude that roughness and heterogeneity strongly affect events sizes, clustering and seismic energy partitioning between fore, main and aftershocks.

Why Do We Need New Models of Earthquake Occurrence?

ZACCAGNINO, D., Sapienza University of Rome, Rome, Italy, davide.zaccagnino@uniroma1.it; TELESCA, L., Centro Nazionale delle Ricerche, Tito Scalo, Italy, luciano.telesca@imaa.cnr.it; DOGLIONI, C., Sapienza Università di Roma, Rome, Italy, carlo.doglioni@uniroma1.it

While modelling the coseismic phase is relatively simple, a comprehensive, effective theory of seismic occurrence is difficult because of strongly nonlinear long-range interactions taking place in the brittle crust, so that fault systems cannot be reduced to simple non-interacting «planes of slip». Moreover, earthquake dynamics not only depends on the rheological properties of rocks, but also on their structural complexity and on intricate stress patterns inside the crustal volumes. Therefore, seismicity showcases different behaviours depending on the spatial and temporal scales of investigation because each level of complexity of the seismogenic source is associated with emergent properties that cannot be derived from the elementary laws ruling the system at a fundamental level. So, we need to set up new models able to reproduce