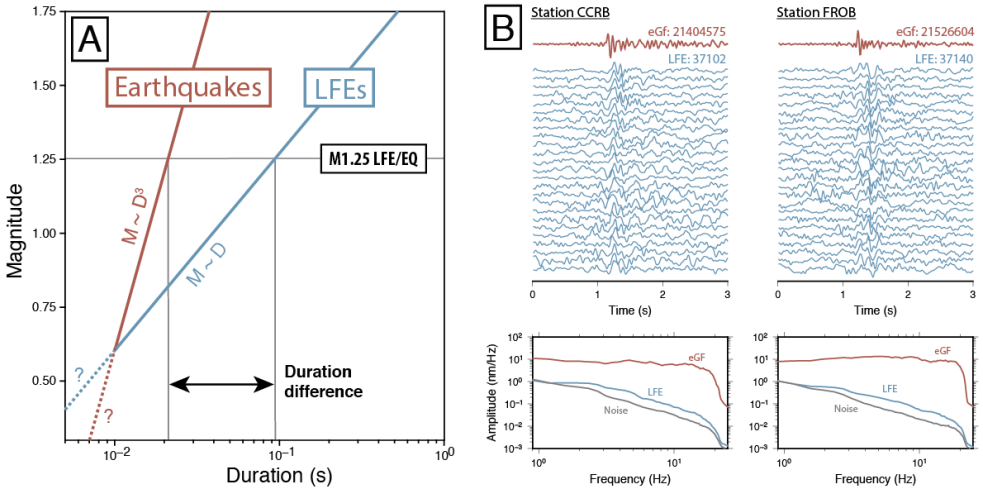
Low-frequency earthquakes (LFEs) are earthquakes that are depleted in high-frequency content relative to earthquakes of similar magnitude. Along the San Andreas Fault, and in the Cascadia subduction zone, LFEs occur in rapid succession, forming tectonic tremor. Here we present results from LFE source studies in both Parkfield and Cascadia. In Parkfield, we use an empirical Green's function approach to investigate which physical properties of the LFE source cause high-frequency depletion. We use a dataset of approximately one million LFEs comprising 88 LFE families on the deep San Andreas Fault. For a subset of the shallowest LFE families, there are nearby earthquakes that locate within 3 km of the LFE hypocenter (a small fraction of the path length). We exploit the assumed difference in moment-duration scaling between LFEs and regular earthquakes and use these earthquakes as empirical Green's functions. We find that source time functions have approximately the same duration at many different seismic stations, independent of source-station azimuth. Using a kinematic rupture model, we find a characteristic duration of 0.6 s and rupture extent of ~300m implying a rupture velocity of 0.15β. When combined with the small magnitude of the LFEs, we infer a stress drop between 1 and 10 kPa, 2-3 orders of magnitude smaller than traditional earthquakes. In Cascadia, we employ 130 low-frequency-earthquake (LFE) templates representing tremor sources on the plate boundary below southern Vancouver Island to examine LFE magnitudes. Template displacement waveforms for direct P- and S-waves at near epicentral distances are remarkably simple at many stations, approaching the zero-phase, single pulse expected for a point dislocation source in a homogeneous medium. Upon correction for 1-D geometrical spreading, attenuation, free-surface magnification and radiation pattern, we solve a large, sparse linear system for 3-D path corrections and LFE magnitudes for all detections corresponding to a single ETS template. After estimating LFE durations and magnitudes we find that LFE duration displays a weaker dependence upon moment than expected for self-similarity, suggesting that LFE asperities are limited in dimension and that moment variation is dominated by slip. This behavior implies that LFEs exhibit a scaling distinct from both large-scale slow earthquakes and regular seismicity. Assuming a slip budget of 4 cm/yr, we estimate characteristic fault slip of 1.5 × 10−4 m, fault dimension of 500 m and stress drop of 10 kPa for a MW 2 LFE, with a characteristic rupture velocity of 1 km/s.



Panel A: Proposed magnitude-duration scaling for regular and slow earthquakes [Ide et al. 2007]. For typical earthquakes (blue) moment increases with the cube of duration while for LFEs (red) moment is proportional to duration. Black lines highlight the duration difference between an example M1.25 target LFE and eGF pair. Panel B: Example nearby earthquake (red) and LFE (blue) velocity waveforms and displacement spectra for stations SMNB and CCRB. Waveforms are bandpassed filtered between 1-20 Hz.