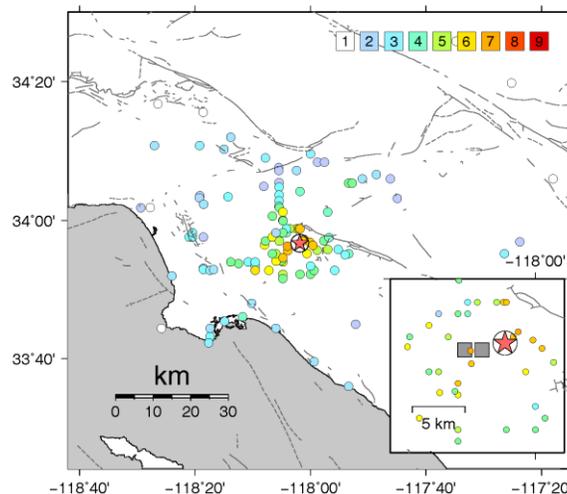


Evidence for Damaging Induced Earthquakes during the Early 20th Century in the Los Angeles Basin

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Recent studies have presented evidence that early- to mid-20th century earthquakes in Oklahoma and Texas, including a number of damaging events, were likely induced by fossil fuel production and/or injection of wastewater (*Hough and Page, 2015; Frohlich et al., 2016*). Considering seismicity from 1935 onward, *Hauksson et al. (2015)* concluded there is no obvious evidence for significant induced activity in the greater Los Angeles region either in recent years or during the 20th century after 1935. To explore a possible association between early 20th century earthquakes and oil and gas production during the initial oil boom in the region, we first revisit the historical catalog as established from macroseismic observations and early instrumental data. We then review oil industry activities during this period. While early industry activities did not induce large numbers of earthquakes, we present evidence for an association between the initial oil boom in the greater Los Angeles area and earthquakes between 1915 and 1932, including the damaging 21 June 1920 Inglewood and 8 July 1929 Whittier earthquakes. Both of these events occurred shortly after notable drilling and/or production activities in the immediate vicinity of the event locations; detailed intensity data for both events are also consistent with the characteristic intensity signature of induced earthquakes proposed by *Hough (2014)*. We further consider whether the 1933 M_w 6.4 Long Beach earthquake might have been induced, and show some evidence that points to a causative relationship between the earthquake and activities in the Huntington Beach oil field. The hypothesis that the Long Beach earthquake was either induced or triggered by an induced foreshock cannot be ruled out. Available records suggest that the likelihood of induced earthquakes was not controlled solely by the total volume of oil produced, but at least in part by the depth and location of production wells.



Intensity distribution of 8 July 1929 Whittier earthquake (red star) determined from unpublished detailed field notes (C.F. Richter, 1929). Gray squares in inset map indicate the locations of Township/Range/Sections where drilling in the Santa Fe Springs oil field yielded a dramatic increase in production during the \approx 6 months prior to the event.