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Research paper

Assessing the potential of luminescence dating for fault slip rate studies on the Garlock fault, Mojave Desert, California, USA

Belinda Roder[a], Mike Lawson[a], Edward J. Rhodes[a,*], James Dolan[b], Lee McAuliffe[b], Sally McGill[c]

[a] Department of Earth and Space Sciences, University of California, Los Angeles, 595 Charles Young Drive East, Los Angeles, CA 90095-1567, USA
[b] Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, USA
[c] Department of Geological Sciences, California State University, San Bernardino, 5500 University Parkway, San Bernardino, CA 92407, USA

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ABSTRACT

Although there has been significant advancement of OSL (optically stimulated luminescence) dating of quartz and feldspar over the past decade, the luminescence characteristics of quartz grains in many tectonically active areas are not suitable for accurate age determinations using this technique. This study investigates the reasons for this unsuitability and tests a new measurement protocol (ITL), which appears more promising. At two sites along the central Garlock fault in the Mojave Desert, California, USA, samples collected for OSL dating for this study have proven problematic. At the El Paso Peaks (EPP) trench site, a sequence of OSL samples was collected from sandy units with a well-established radiocarbon chronology, providing the opportunity to assess different approaches and optimize our luminescence dating procedures. At Christmas Canyon West (CCW), where future Garlock fault slip rate studies will be conducted using luminescence dating, samples were collected to assess the luminescence characteristics of both quartz and feldspar in this environment. At both sites, signals from quartz and K-feldspar grains are consistently dim. At EPP, quartz results provide age underestimates, while K-feldspar IRSL yields erratic values; the causes of this problematic behavior are unclear. Preliminary minimum isothermal thermoluminescence (ITL) signals of K-feldspar measured during preheating appear to be consistent with the radiocarbon age estimates, demonstrating potential for accurate age determination in this kind of environment using this protocol.

1. Introduction

Despite significant advances in OSL (optically stimulated luminescence) dating of quartz over the past decade, in many tectonically active areas the luminescence characteristics of quartz grains are not well suited for the determination of precise age estimates (Rhodes, 2011). Problems encountered include low OSL signal sensitivity of both quartz and potassium feldspar (K-feldspar) and in some cases, age underestimation (Preusser et al., 2006; Steffen et al., 2009). In order to study these problems, and to develop methods capable of providing reliable age estimates in these environments, quartz and K-feldspar samples were investigated from two locations along the Garlock fault in California, USA.

The Mojave Desert, California, USA, is crossed by a number of major active fault systems that have played an important role in landscape development and represent a significant seismic hazard. Several significant, surface-rupturing earthquakes have occurred in the region during historic time, including the 1872 M (moment magnitude) 7.6 Owens Valley earthquake, the 1992 M 7.3 Landers earthquake and the 1999 M 7.1 Hector Mine earthquake. The Garlock fault is one the major active strike-slip faults in southern California, extending 250 km in a broad east–west arc from its intersection with the San Andreas fault to the southern end of Death Valley (Fig. 1). Critical questions of neotectonic studies include the degree to which fault slip is clustered into episodes of rapid movement, followed by periods of reduced activity, and whether slip is accommodated by different sub-parallel faults within a single system (Dolan et al., 2007; Frankel et al., 2011). These issues are important for understanding fault dynamics and improving earthquake risk assessment. One key to solving these issues is to document fault slip rates at a variety of timescales.

The El Paso Peaks (EPP) and Christmas Canyon West (CCW) sites were investigated along the central Garlock fault in the Mojave Desert, California (Fig. 1). At the EPP paleoseismic site, a comprehensive radiocarbon chronology exists (McGill and Rockwell, 1998; Dawson et al., 2003; see online Supplementary data) providing

* Corresponding author. Tel.: +1 310 825 3463.
E-mail address: erhodes@ess.ucla.edu (E.J. Rhodes).

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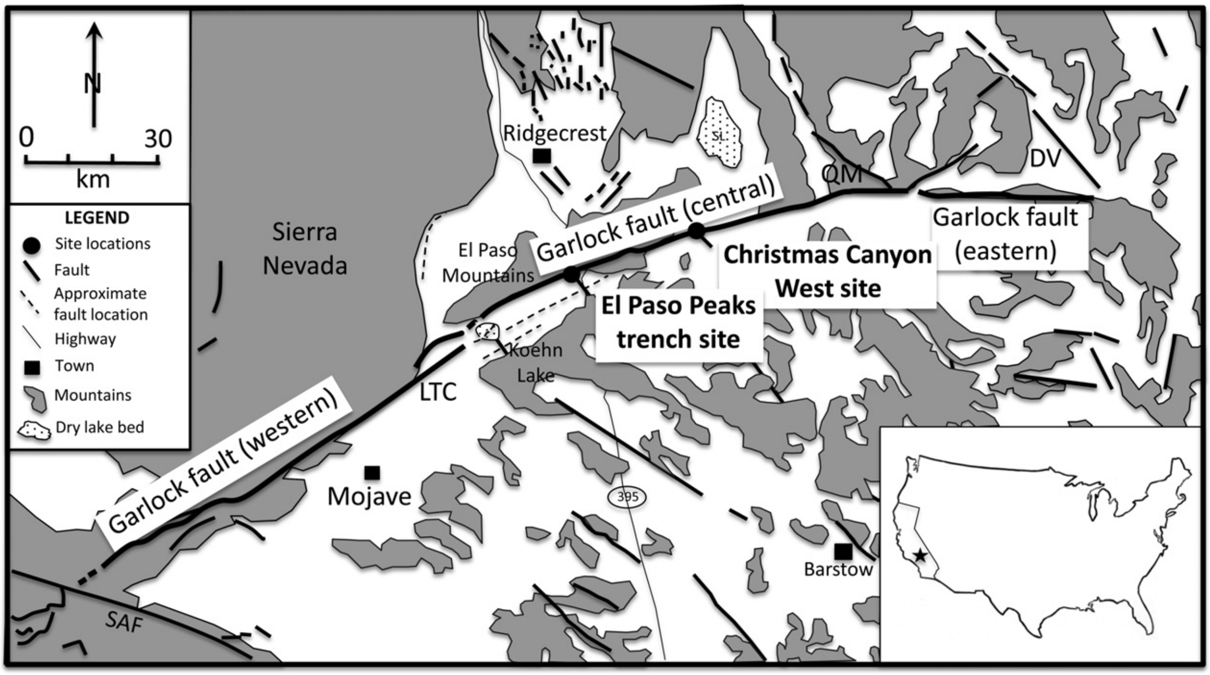

Fig. 1. Map showing the location of the Garlock fault, El Paso Peaks trench site and Christmas Canyon West site, California, USA. Inset: map outline of USA with California highlighted, and location of the sites marked with a star. SAF is San Andreas fault, GF is Garlock fault, LTC is Lone Tree Canyon, SL is Searles Lake (dry), QM is Quail Mountains, DV is Death Valley.

excellent independent age control for comparison to samples collected for OSL dating. The abundance of organic material at this site is exceptional in this region; the application of luminescence dating can be used for fault slip rates and paleoseismic studies where sufficient organic material is not present. The CCW site is located on a sandy alluvial fan surface that has been offset by the Garlock fault, providing the potential for fault slip rate estimates. At this site, the luminescence characteristics of quartz and feldspar in this region were investigated. The eventual goal of this project is to 1) refine and optimize optical dating of neotectonic contexts in southern California and 2) determine late Holocene slip rates for the Garlock Fault and improve constraints for the paleoseismic record. OSL and IRSL (infrared stimulated luminescence) dating have a key role to play in neotectonic studies as a supplement to other dating techniques, or as an alternative where organic material is not present for radiocarbon dating.

2. Sampling sites

Sediment samples were collected from two sites on the central Garlock fault in the Mojave Desert, California. The El Paso Peaks (EPP) trench site was first explored by McGill and Rockwell (1998) to investigate paleoseismic evidence for Holocene rupture events and later re-opened by Dawson et al. (2003) in order to refine and extend the paleoseismic record at this site. From these two studies, 30 samples (27 detrital charcoal, 2 twig and 1 shell) from this site have been radiocarbon dated (see online Supplementary Table 1). The EPP site sits at the center of a small playa that is adjacent to the Garlock fault, and surface-rupturing earthquake events on the fault caused the stratigraphy within the playa to become disturbed. The relationships between the disturbed and undisturbed stratigraphic units can be used to identify individual earthquake events on the Garlock fault. Six well-resolved paleoearthquakes events spanning the last ~7000 years have been identified at this site. The playa is confined to the northwest by the El Paso Mountains and to the southeast by a shutter-ridge composed of gravelly alluvial fan deposits. The playa is prevented from freely draining by a small alluvial fan, which has been formed by the same ephemeral stream that is the source of sand and silt forming the playa sediments (Dawson et al., 2003). There has been semi-continuous deposition throughout the Holocene, as suggested by lack of evidence of surface erosion, the almost complete absence of soil development, and a lack of extensive bioturbation except at the playa margins (Dawson et al., 2003). The playa sediments are composed of well-stratified, distinctive units of graded sand and silt interpreted to represent individual flood events or pulses of a single flood event (Dawson et al., 2003). McGill and Rockwell (1998) found that the flood frequency history of the playa parallels the sedimentation rate history, which may reflect climate change or changes in drainage patterns. These units are laterally extensive and easily correlated within the trench. The sediments at this site are comprised of approximately 10% quartz, 70% feldspar, 20% other minerals and lithic fragments. In this study, the EPP trench was re-opened near the center of the playa to a depth of approximately 5 m. A sequence of samples for OSL dating was collected, bracketed by units that have been previously dated. This site provides the opportunity to compare OSL and IRSL age estimates with an existing independent radiocarbon chronology (Fig. 2).

The Christmas Canyon West (CCW) site is located approximately 30 km eastward from the El Paso Peaks site along the Garlock fault. Here, alluvial fan features that have been offset by movement on the Garlock fault have been identified using high-resolution LiDAR images (see online Supplementary Fig. 1). Because of the proximity of these two sites, it is inferred that the paleoearthquakes events identified in the EPP trench are the same events that have caused the offsets observed at CCW. The alluvial fan surface is composed predominately of coarse to medium sand, with minor fine to medium gravels, and is not well-stratified. A one meter deep pit was dug approximately 10 m to the south of the fault trace, and five samples from these fluvial sediments were collected as a pilot study to asses the luminescence characteristics of quartz and feldspar in this region for future slip rate assessments in similar contexts.