Luminescence sensitivity enhanced by residence time in the critical zone

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The emerging field of quartz luminescence properties in Earth-surface processes research shows promise, with optically stimulated luminescence (OSL) sensitivity proposed as a valuable tool for provenance or sediment history tracing (e.g., Gray et al., 2019; Sawakuchi et al., 2020). However, the geological mechanisms driving quartz sensitization remain under investigation.We study the influence of source rock and surface processes on the luminescence properties of quartz sand from bedrock and modern and Late Pleistocene alluvium generated from a steep, small (52 km^2) catchment in northern Utah, USA. Continuous wave and linear modulated OSL are used to calculate OSL sensitivity and characterize the intensity of the fast-decay component. We compare OSL sensitivity with sand-grain provenance and proxies for surface processes such as topographic metrics, cosmogenic ^{10}Be-derived erosion rates, chemical weathering indicies, and magnetic susceptibility.

Our results indicate that the Late Pleistocene alluvium has low OSL sensitivity that is similar to the bedrock source, but that the modern alluvium has enhanced luminescence properties with no clear relationship to bedrock sources in their prospective catchment areas. OSL sensitivity has an inverse relationship with catchment-averaged erosion rates and a positive relationship with chemical weathering indices and magnetic susceptibility. We suggest that changes in critical-zone processes between the effectively wetter, cooler Pleistocene and the dryer, warmer conditions of the Holocene modulated the luminescence properties. The similarity in OSL sensitivity between the Pleistocene alluvium and the quartzite bedrock implies that surface processes during the last glacial period did not lead to enhanced OSL sensitivity. In contrast, modern sediments show low catchment-averaged erosion rates, more intense chemical weathering, and increased magnetic susceptibility suggesting that modern sediment supplied to the stream has maintained longer residence time in the critical zone compared to the Pleistocene alluvium.

We conclude that the OSL sensitization in the modern sand is due to the climate-mediated increase in sediment exposure to ionizing radiation, sunlight and/or fires during longer residence time in the shallow critical zone. As such, changes in chemical or physical weathering rates and the related sediment reworking between different mean climate-states appear to be encoded in the luminescence properties of quartz sand. This study has implications for the utility of luminescence properties for bedrock provenance and as a proxy for the rates and processes of sediment transport, erosion, and weathering within the critical zone.

Keywords (max. 5): OSL sensitivity, fluvial sediments, critical zone, chemical weathering

References

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