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Climate- vs. Earthquake-induced Rock-Glacier Advances in the Tien Shan: Insights from Lichenometry

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Rock glaciers have been traditionally used as landform proxies of the distribution of sporadic alpine permafrost. In the northern Tien Shan mountains of Kyrgyzstan, most distinct lobes of >200 rock glaciers that we mapped from satellite imagery occur at two major elevation levels. However, a number of particularly low-lying lobes seem difficult to reconcile with palaeoclimatic fluctuations and commensurate changes of permafrost patterns: The minimum elevation of the majority of rock-glacier snouts lies between ∼2500 up to ∼3700 m a.s.l., but some 10% of rock-glaciers extend down to well below 3000 m a.s.l.

We hypothesize that some of the rock glaciers in this area may have formed following strong earthquakes that could have triggered massive supraglacial rock-slope failures, which would have subsequently created sediment-rich rock glaciers from clear-ice glaciers. Our hypothesis is based on the observation that the tectonically active northern Tien Shan of Kyrgyzstan and Kazakhstan was affected by a series of major earthquakes in the late 19th and earliest 20th centuries, e.g. in 1885 (Ms 6.9), 1887 (Ms 7.3), 1889 (Ms 8.3), and 1911 (Ms 8.1). All of these earthquakes had triggered numerous landslides in the northern Tien Shan. It is also likely that similarly strong earthquakes had happened before, but their recurrence intervals are long and more palaeoseismological work is in progress.
We test whether lichenometry of rock-glacier surfaces together with morphometric analysis are suitable methods to testing our hypothesis. We focus on assessing the possibility of earthquake-triggered rock-glacier advances, and use lichenometry to resolve age patterns of different rock-glacier lobes. We use a dataset of several thousand lichen diameter measurements encompassing seven different species calibrated by gravestones and dated mass-movement deposits. Data on four single and two merging rock glaciers in four selected valleys in Kyrgyzstan and Kazakhstan support the notion that Tien Shan rock glaciers do not record a consistent palaeoclimatic signal.

We discuss whether distinct peaks of comparable lichen sizes and associated distributions of surface velocities for a given rock-glacier lobe result from rapid climate-driven advances or high lateral material input provided by seismically-induced slope instability instead. We compare our field data to advance-rate estimates from ground surveys and remote sensing (1 to >10 m/a), and dendrogeomorphic constraints obtained from trees growing on the rock glaciers. We conclude by highlighting a number of constraints that may limit the use of lichenometry for dating rock-glacier advances, and scope for future research on seismic triggers.