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Quantification of the rate of morphometric change of alpine cirques over 0.75 Myr in the Ben Ohau Range, New Zealand

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The intractable obstacle to understanding cirque evolution has been the lack of an independent timescale against which to measure morphometric change. By using known rates of transport and uplift of the Southern Alps, combined with the oxygen isotope record contained in marine sediments, it is possible to estimate the duration of glacial occupancy of cirques in the Ben Ohau Range. The pattern is one of very limited glaciation of the southern range, with glacial occupancy increasing northwards. Map-based measurement of 18 morphometric properties in each of 92 cirques reveals systematic northward trends in cirque size, form and altitude, which are explained as reflections of increasing cirque "age" (i.e. length of glacial occupancy). Thus, the validity of space-time substitution is demonstrated rather than assumed, and morphometric trends define evolutionary stages of cirque development. For cirques with up to c.750 kyr occupancy, rates of downcutting average 0.29 mm a^{-1} and headwall retreat 0.44 mm a^{-1}. There is no indication of attainment of an equilibrium form within this time: both cirque size and form continue to evolve throughout. Indeed, few parameters show a convergence of value with cirque "age", suggesting that the cirques are not tending towards equilibrium form. Some morphometric parameters perform much better than others: the k coefficient of the long-profile descriptor is the most powerful predictor of cirque "age", and simple measures perform better than derived measures (e.g. ratios of dimensions). The trends identified concur with some previously published ideas, but for the first time provide empirically-quantified rates of change at an appropriate timescale.