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Headward retreat of streams in the Late Oligocene to Early Miocene Swiss Alps

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Few primary records of the early evolution of the Alps exist. Here, we use a detailed secondary record, namely the deposits in the central segment of the Swiss Alpine foreland together with numerical and empirical models to propose that the Alpine topography evolved from an early transient state where streams adjusted to rock uplift by headward retreat, to a phase where any changes in rock uplift were accommodated by vertical incision. The first stage comprises the time interval between ca. 31 and 22 Ma and represents a period of transient orogenic growth. During this phase, the flux of material entering the orogen exceeded the erosional flux. Our models suggest that the overall elevation of the range increased rapidly within <5 Mys. The drainage system also evolved rapidly during this phase. Initially, numerous small streams incised headward into the growing plateau. In the foreland basin, these streams deposited many small fans with a lateral spacing of <30 km. As the range evolved, the streams joined and the fans coalesced into a few large depositional systems with a lateral spacing of ca. 80-100 km at 22 Ma. The mean pebble size within these deposits remained constant, suggesting constant climatic conditions. The variability in pebble size, however, increased due to enhanced orographic effects and storminess at higher altitudes. Additionally, the provenance of the sediment shifted, with increasing crystalline content in the younger rocks as the streams eroded farther into the range. By 22 Ma, the drainage system had completely occupied the landscape and a period of mainly vertical downcutting ensued, delineating the second stage. The major Alpine streams had established themselves, and only two large rivers carried material into the foreland fans. This phase of vertical erosion was maintained until at least 15 Ma, and potentially till 5 Ma when the uplift and erosion of the Molasse started, and streams were redirected both in the Alps and in the foreland.