15. Özcan, A. S. . Texture of $TiSi_2$ thin films on Si(001). . . **92,** 5011–5018 (2002).
16. Tsukada, M. & Ohfuji, S. Structural inheritance from polycrystalline underlayers in the growth of double-layered aluminum films. . . . . **11,** 326–332 (1993).
17. Tracy, D. P., Knorr, D. B. & Rodbell, K. P. Texture in multilayer metallization structures. . . . **76,** 2671–2680 (1994).
18. Knorr, D. B., Merchant, S. M. & Biberger, M. A. Development of texture in interconnect thin film stacks. . . . . **16,** 2734–2744 (1998).
19. Joint Committee on Powder Diffraction Standards. . 38–0844 (International Centre for Diffraction Data, Philadelphia, 1998).
20. Kilaas, R. Optimal and near-optimal filter in high-resolution electron microscopy. . . **190,** 45–51 (1998).

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Depart6.6(e)0 TJ-0.3628 -1.1879 TD[(N)31.9(e)0(w)-267.8(H)0(a)19.8(ven,)-261.2(Conn)12.4(ecticut)-267(06511,)-266.1(USA)]TJ/F3 1 Tf5.9774 0 0 5.3127 45.8079 311.6976 Tm(2)Tj/F4 1 Tf7.9702 0 0 7.9702 48.6992
significant component of magmatically controlled heating.

Apatite He ages in this swath of the central Cascades vary from 4.4 to 60 Myr

BP (Fig. 1). In single vertical transects collected over short horizontal distances, ages generally show increasing ages, or little change in age, with increasing elevation[21]. The most obvious pattern in the data consists of relatively old ages (>25 Myr BP) at the topographic crest and far eastern and western flanks of the range, and young ages (<12 Myr BP) on the west slope (Figs 1 and 2).

To first order, the ratio of the apatite He closure isotherm depth (~1.5–2.5 km) and age yields an estimate of time-averaged exhumation rate. As there are no known late Tertiary faults or extensional structures in this region[15–19], we assume that this exhumation is entirely erosional. We calculated erosion rates for these samples by relating each apatite He age to cooling-rate-dependent closure temperature and depth through a series of equations with assumed parameters, including geothermal gradient, He diffusion properties[20] topographic effects by adding the difference between sample and which is highest in the far western part of the transect, rather than at a mean elevation of ~1 km on the west flank, at the coincidence of erosion rate and precipitation maxima.

No major late Tertiary structures have been identified in the Cascades that could accommodate differential uplift and erosion rates across the range. It is possible that broad arching or folding could lead to higher uplift rates in the core of the range, but by itself (and in a steady state) this would be expected to lead to the highest erosion rates at the topographic crest, rather than 50 km to the windward side, coincident with the highest precipitation. Because of this, we conclude that the long-term erosion rate pattern across the range is controlled primarily by the precipitation pattern. The specific geomorphic processes coupling precipitation and erosion in this case are not clear.

Commonly used stream-power indices predict erosion as a function of main channel slope and discharge, but neither of these parameters correlate with precipitation or erosion rates inferred from apatite He ages. This may suggest a more important role for hill-slope processes or higher-order stream characteristics in controlling variations in long-term erosion rates, because these respond to more local variations in precipitation. Alternatively, variations in extents of glacial erosion across the range may contribute to the spatial pattern of erosion, because ice accumulation would also respond to local variations in precipitation. But, regardless of the specific geomorphic liaison between climate and erosion, these data suggest a predominately climatic influence on spatial variations in erosion rates across the range.

The strong variation in, and correlation between, precipitation and erosion rates across the Washington Cascades supports theoretical studies that argue for strong coupling and feedbacks between climate and tectonics in active orogens[1–10]. Modelling studies suggest that mountain topography evolves towards a steady state, after which the macro-scale topography remains constant and erosion rates are equal to rock uplift rates. It is possible that rock uplift and erosion rates are unrelated, in which case the modern Cascades topography is transient.

However, if the Cascades are in, or even close to, topographic steady state, then rock uplift on the west flank is as much as an order of magnitude faster than elsewhere in the range. The dynamic link by which rock uplift and deformation respond to spatially focused erosion could simply be isostasy, or some other mechanism such as accomodation of pluton emplacement or the vertical component of middle or lower crustal flow into crustal regions experiencing relatively rapid exhumation. In either case, the current orographic climate pattern is well correlated with, and may exert a strong influence on, the distribution of erosion, and possibly rock uplift and deformation, across the Cascades. □

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1. Beaumont, C., Kooi, H. & Willett, S. in (ed. Summerfield, M. A.) 29–55 (John Wiley & Sons, Chichester, UK, 2000).
2. Willett, S. D. Orogeny and orography: The effects of erosion on the structure of mountain belts. **104,** 28957–28981 (1999).
3. Zeitler, P. K. . Erosion, Himalayan geodynamics, and the geomorphology of metamorphism. **11,** 4–9 (2001).
4. Koons, P. O. The topographic evolution of collisional mountain belts: A numerical look at the southern Alps. **289,** 1041–1069 (1989).