contrast, a person takes shorter strides and is slower during skipping than during running[1]. Furthermore, quadrupedal galloping is a smooth gait[6] that involves lower forces in muscles, tendons and bones than trotting at fast speeds[7,8]. In contrast, skipping is a jolting gait that involves greater forces than walking or running[1]. Finally, a quadruped consumes less metabolic energy to travel one kilometre at high speed by galloping than by walking or trotting[9]. In contrast, a person consumes more metabolic energy by skipping than by walking or running[1]. The reason for the high metabolic cost of skipping, despite the tricks used to conserve mechanical energy, may be that the muscles must generate higher forces for skipping than for other gaits[10].

In short, skipping is slow, jolting and tiring. This must be why most people abandon skipping when they become sensible adults. For children, however, the sheer joy of skipping seems to outweigh these rational considerations. □

*Claire T. Farley is at the Locomotion Laboratory, Department of Integrative Biology, 3060 Valley Life Sciences Building, University of California, Berkeley, California 94720-3140, USA.*
*e-mail: cfarley@socrates.berkeley.edu*

1. Minetti, A. E. *Proc. R. Soc. Lond. B* **265,** 1227–1235 (1998).
2. Cavagna, G. A., Heglund, N. C. & Taylor, C. R. *Am. J. Physiol.* **233,** R243–R261 (1977).
3. Alexander, R. M. *Elastic Mechanisms in Animal Movement* (Cambridge Univ. Press, 1988).
4. Clark, J. E. & Whitall, J. in *Development of Posture and Gait Across the Life Span* (eds Woolacott, M. H. & Shumway-Cook, A.) 128–151 (Univ. South Carolina Press, Columbia, 1989).
5. Caldwell, G. E. & Whitall, J. *J. Motor Behav.* **27,** 139–154 (1995).
6. McMahon, T. A. *J. Exp. Biol.* **115,** 263–282 (1985).
7. Farley, C. T. & Taylor, C. R. *Science* **253,** 306–308 (1991).
8. Biewener, A. A. & Taylor, C. R. *J. Exp. Biol.* **123,** 383–400 (1986).
9. Hoyt, D. F. & Taylor, C. R. *Nature* **292,** 239–240 (1981).
10. Kram, R. & Taylor, C. R. *Nature* **346,** 265–267 (1990).

**Geology**

# Early uplift in Tibet?

**William Ruddiman**

On page 769 of this issue, Chung *et al.*[1] report evidence of potassium-rich volcanism about 35 million years ago in the northeastern Tibetan plateau, and infer that this region rose long before the southwestern part of the plateau. That has ramifications both for the tectonic history of the plateau and its suspected role in cooling the planet.

The Tibetan plateau covers 10° of latitude and 20° of longitude, more than a million square kilometres (Fig. 1). All of it lies above 5,000 m, high enough to bury the tallest peaks in the Alps and the Rockies. Its bedrock geology is still mostly unexplored, particularly in the north, and especially by techniques that constrain the timing of uplift. As a result, scientists often speak of the plateau as if describing a piston that has risen as a single unit.

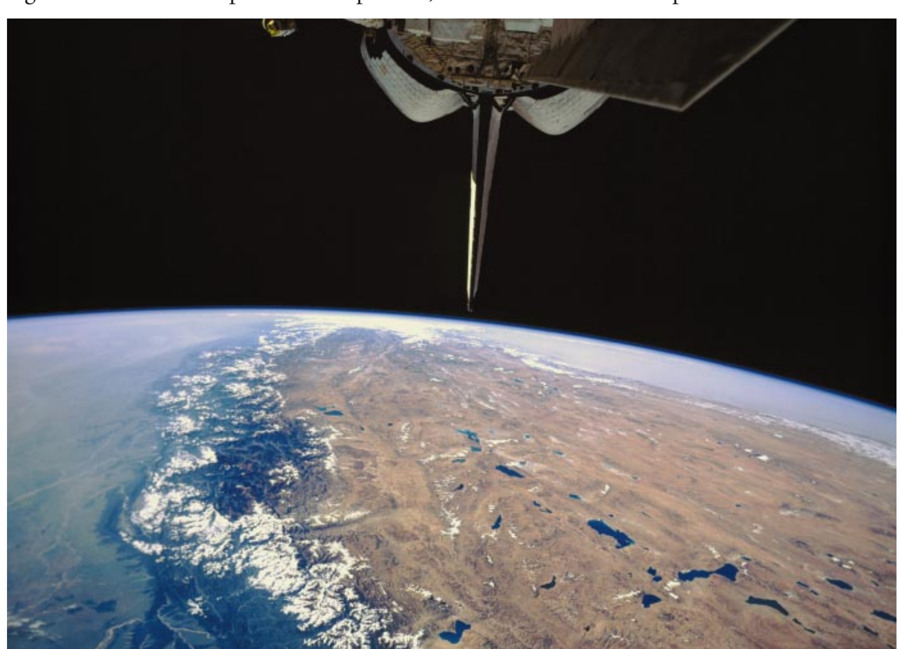
In this picture, uplift was slow for the first 35 Myr (million years) after the initial collision between India and Asia, 55 Myr ago. But then, by 20 Myr ago, high topography had appeared. Its presence can be inferred from geochemical clues that show how long it takes minerals to move from hot regions many kilometres deep to exposure at the surface. This kind of evidence points to rapid 'unroofing' in the Himalayas and southern Tibet by 20 Myr ago, requiring rapid erosion, which in turn indicates that the surface was high[2]. In addition, sediments eroded from the high Himalayas began to be deposited at slightly higher rates on the Indian Ocean floor around 20 Myr ago, and then at much higher rates ten million years later[3]. This also suggests that rapid uplift only took place in Tibet in the past 20 Myr.

But this evidence is biased towards the fast-eroding high Himalayan mountains and the well-studied southwestern parts of Tibet. The piston history it provides omits the regional tectonic complexity that is typical of every continental region studied in detail. Continental collisions are inherently messy tectonic processes in time and space[4], so we should expect uplift at different times in different parts of Tibet.

Chung *et al.*[1] move us towards this more detailed view. They find outcrops of potassium-rich volcanic rocks along several tectonic belts (faults and suture zones) crossing the northeastern part of the plateau, mostly between 37 and 33 Myr old. Well-dated volcanic deposits of this kind in southwest Tibet have already been used, together with signs of normal faulting, as evidence that the region has been under tension[5] during the past 20 Myr. The pervasive extensional faulting is usually thought to mean that surface elevation is high — high enough to overcome the compressional stress applied by the collision of continents, allowing the plateau to sag under its own weight. Potassium-rich volcanism fits this picture because it is thought to result from melting in the upper mantle by hot asthenosphere (the more plastic part of the mantle) that has replaced cold lithosphere (the stiffer part of the mantle that usually underlies continental crust). For this replacement to occur, thick lithosphere had to be present in the first place, and then sink deeper into the mantle. Thick lithosphere points to high surface elevations.

By this chain of reasoning, Chung *et al.* infer that elevations in northeastern Tibet were high enough by 37 to 33 Myr ago to generate potassium-rich volcanism. If correct, this indicates much earlier uplift across some northeastern parts of the plateau than in the southwest. But it remains to be shown whether this early volcanism was merely localized near major faults, or was spread across a broad enough region of the plateau to typify much of its large-scale behaviour.

This new evidence also bears on the possible climatic role of the plateau, in the uplift–weathering hypothesis. It has been proposed that uplift of the plateau created and then strengthened the South Asian monsoon[6,7], and that monsoon rains worked in combination with exposure of fresh rock to



NASA/STS41G

Figure 1 **Tibet and the space shuttle's tail. The northeastern part of the Tibetan plateau (towards the lower left in this view) may have risen 15 million years before the better-explored south.**

### 100 YEARS AGO

**When the year's work is over and all sense of responsibility has left us, who has not occasionally set his fancy free to dream about the unknown, perhaps the unknowable? And what should more frequently cross our dreams than what is so persistently before us in our serious moments of consciousness – the universal law of gravitation. We can leave our spectroscopes and magnets at home, but we cannot fly from the mysterious force which causes the rain-drops to fall from the clouds, and our children to tumble down the staircase. What is gravity? … Lord Kelvin is quoted as having pointed out that two sources or two sinks of incompressible liquid will attract each other with the orthodox distance law. Let us dream, then, of a world in which atoms are sources through which an invisible fluid is pouring into three-dimensioned space. … sinks would form another set of atoms, possibly equal to our own in all respects but one; they would mutually gravitate towards each other, but be repelled from the matter which we deal with on this earth. … When the atom and the anti-atom unite, is it gravity only that is neutralised, or inertia also? May there not be, in fact, potential matter as well as potential energy? And if that is the case, can we imagine a vast expanse, without motion or mass, filled with this primordial mixture, which we cannot call a substance because it possesses none of the attributes which characterise matter, ready to be called into life by the creative spark? Was this the beginning of the world?**

From *Nature* 18 August 1898.

### 50 YEARS AGO

**The trouble in Palestine sets back the clock on the recent efforts of both Arab and Jewish gardeners to develop the horticultural attractions of the Holy Land, for the palm boulevards of Jaffa, and the flower-growing settlements at Mishmar-Hasharon, etc., had attracted much praise and attention. The danger, however, goes deeper, for modern Palestine was not the primitive wilderness of brigand and bedouin as depicted in most of the Western religious books. Several excellent gardens and plant collections were in the country, and their future is threatened by the bitterness of war.**

From *Nature* 21 August 1948.

increase physical and chemical weathering, pulling more $CO_2$ out of the atmosphere and so cooling the global climate[8].

The near-consensus of papers in a volume devoted to this topic[9] makes the uplift–weathering hypothesis a leading explanation for global cooling during the past 20 Myr. Still, ignorance of uplift histories across much of Tibet has made the hypothesis difficult to evaluate in full. In particular, with little direct evidence for uplift before 20 Myr ago, it is hard to claim that Tibetan uplift caused, or was even involved in, the global cooling that began 55 Myr ago and led to Antarctic glaciation by 36 Myr ago[10].

If large-scale uplift did occur in northeastern Tibet as early as 37–33 Myr ago, chemical weathering of this high terrain could have contributed to global cooling then. Other evidence supports this idea. A striking increase in the global-ocean $^{87}Sr/^{86}Sr$ ratio began 40 to 35 Myr ago, and the extra $^{87}Sr$ probably came from the Tibet–Himalaya complex[11], from both accelerated weathering and the exposure of rocks rich in $^{87}Sr$. The early uplift inferred for northeast Tibet matches the initial upturn in this signal.

Now the question is whether further exploration of Tibet will find evidence of even earlier uplift, especially during the cooling between 55 and 40 Myr ago[10]. □

*William Ruddiman is in the Department of Environmental Science, Clark Hall, University of Virginia, Charlottesville, Virginia 22903, USA.*
*e-mail: wfr5c@virginia.edu*

1. Chung, S.-L. *et al. Nature* **394,** 769–773 (1998).
2. Harrison, T. M., Copeland, P., Kidd, W. S. F. & Yin, A. *Science* **255,** 1663–1670 (1992).
3. Rea, D. K. in *Synthesis of Results from Scientific Drilling in the Indian Ocean* (eds Duncan, R. A., Rea, D. K., Kidd, B., von Rad, U. & Weissel, J. K.) 387–402 (Am. Geophys. Un, Washington DC, 1992).
4. Molnar, P. *Am. Sci.* **77,** 350–360 (1989).
5. Turner, S. *et al. Nature* **364,** 50–54 (1993).
6. Ruddiman, W. F. & Kutzbach, J. E. *J. Geophys. Res.* **94,** 18409–18427 (1989).
7. Prell, W. L. & Kutzbach, J. E. *Nature* **360,** 647–652 (1992).
8. Raymo, M. E., Ruddiman, W. F. & Froelich, P. N. *Geology* **16,** 649–653 (1988).
9. Ruddiman, W. F. (ed.) *Tectonic Uplift and Climate Change* (Plenum, New York, 1997).
10. Miller, K. G., Fairbanks, R. G. & Mountain, G. S. *Paleoceanography* **2,** 1–19 (1987).
11. Richter, F. R., Rowley, D. B. & DePaolo, D. J. *Earth Planet. Sci. Lett.* **109,** 11–23 (1992).

**Neurobiology**

# Making smooth moves

**Terrence J. Sejnowski**

Whether reaching, throwing, running or dancing, our natural tendency is to make smooth and precise movements. Out of the infinite number of ways that we could have made a particular movement, we generally pick the one that is the smoothest. The current thinking in the field of motor control is that the smooth, stereotyped trajectories made by our motor system are specially chosen to minimize jerkiness[1,2] and to maximize efficiency[3]. Or could it be that smoothness is a by-product of a more fundamental computational goal of the motor system, a goal that only makes us look graceful by accomplishing something else?

On page 780 of this issue[4], Harris and Wolpert propose an alternative to the principle of maximum efficiency: the principle of maximum precision. On the face of it, making a precise movement does not seem to imply smoothness. Imagine that the goal is to touch an object as precisely as possible in a fixed amount of time. Getting to the spot as

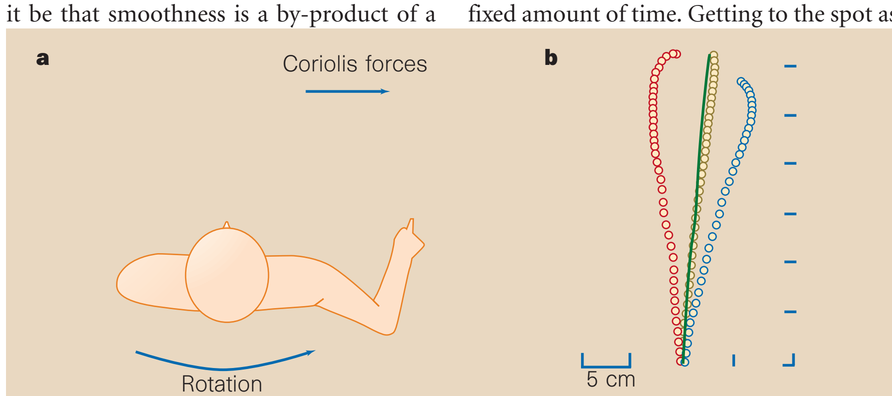



Figure 1 **Hand trajectories for reaching before and after rotation of the body, showing that smooth movements are made even after adaptation in an altered environment.** a, **The subject was on a turntable and slowly rotated.** b, **View from above of average reaching movements, made in darkness to the position of a visual target that was extinguished just before the subject reached for it. The initial trajectories after the start of rotation (blue circles) were seriously affected by Coriolis forces, but after 40 arm movements (yellow circles) the accuracy and velocity profile of the trajectory was almost identical to that of the original movement (green line). After the rotation stopped, the initial trajectory (red circles) shows the after-effects of rotation. (Adapted from ref. 7.)**