ORIGINS OF LIFE

Shock synthesis

When asteroids or comets smash into Earth, they form craters such as the one at Gosses Bluff, Australia (pictured). But could such an impact have kick-started life on our planet? Nir Goldman and colleagues have modelled what happens inside cometary ice when it smashes into a planet (N. Goldman *et al. Nature Chem.* doi:10.1038/nchem.827; 2010). They find that, under certain circumstances, complexes form that can act as precursors to glycine, the simplest amino acid.

The idea that comets delivered organic molecules to the early Earth is disputed, because the extreme heat generated by the impact would probably have incinerated such a cargo. An alternative theory is that the heat and pressure of cometary impacts could have caused material on Earth's surface to react to form organic compounds. But the early Earth's chemical environment isn't thought to have been conducive to such reactions.

Impacts in which Earth was struck glancingly, however, would have generated much lower temperatures within cometary ice, allowing organic matter to survive. Goldman *et al.* therefore used quantum molecular dynamics to simulate events inside cometary ice during such collisions.

S. ALVAREZ/NAT'L GEOGR. STOCK

The authors modelled a mixture of water, methanol, ammonia, carbon monoxide and carbon dioxide under conditions of shock compression, and found that many products were formed — including oligomers that contained the carbon–nitrogen bonds required for amino acids. Subsequent quenching of the model system to lower pressures and temperatures broke the complexes into smaller fragments, including a glycine–CO_2 complex.

Of course, we may never know how life began on Earth. But Goldman *et al.* calculate that the probability that any particular cometary impact will generate shock waves of the size modelled is 17% — well within the realms of possibility.

Andrew Mitchinson

of genes essential to achieving the ground state of pluripotency. What, then, are the prospects for resetting the differentiation propensity of iPSCs? The results of both studies suggest that this could be achieved by either repeated reprogramming or continuous subculturing (passaging) of iPSCs — or perhaps by using demethylating drugs.

These findings[2–4] are a reminder that our understanding of the pluripotent state is still primitive, and that the mechanisms of both transcriptional and epigenetic control of reprogramming should be explored further. They also indicate that not all iPSC lines will be equal in their differentiation capacity, regardless of the care taken to ensure faithful reiteration of the ground state. These differences may simply reflect a series of glitches in the reprogramming protocol, suggesting that many more iPSCs could potentially be coaxed to follow a trajectory towards classical ESC pluripotency. If the goal of somatic-cell modification is to achieve a fully naive ground state of pluripotency, then SCNT may be preferable to transcription-factor-based reprogramming. But if differentiation to a particular cell lineage is desired, iPSC lines biased towards that lineage could be used, especially if the lineage is difficult to obtain using authentic ESCs.

The three papers[2–4] also compel us to look more carefully into reports documenting transcription-factor-driven direct reprogramming of one somatic cell into another — for instance, exocrine pancreatic cells into β-cells[7], or fibroblasts into neurons[8] or heart muscle[9]. Thus, retention of epigenetic memory may have a more significant impact on the cellular characteristics than is currently appreciated. Finally, it has been suggested that at least some somatic-cell lineages are modified at the DNA level (for example, by transposons)[10], hinting that the memory of DNA methylation may extend to DNA sequences in iPSCs obtained from such cells.

Ultimately, it seems as though we have different reprogramming tools on hand that produce slightly different pluripotent stem cells. Rather than asking which of these tools is likely to yield superior results, the focus should be on the most appropriate application for each method. It must be kept in mind, however, that authentic ESCs remain the gold standard against which all reprogramming technologies must be judged. ■

Thomas P. Zwaka is at the Baylor College of Medicine, Center for Cell and Gene Therapy, Houston, Texas 77030, USA.
e-mail: tpzwaka@bcm.edu

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EARTH SCIENCE

Glaciers shield mountain tops

Jean Braun

Glaciers frozen to bedrock may have protected the southernmost Andes from erosion, providing an explanation for the mountains' topography and fresh constraints on possible links between climate and tectonics.

Most geologists would agree that mountain glaciers, which appeared some 3 million to 5 million years ago in response to Earth's slowly cooling climate, are responsible for erosionally shaping most mountains into their jagged present-day morphology. However, an extensive data set collected by Thomson and co-authors (page 313 of this issue[1]) provides evidence that glaciers have protected rather than eroded the high-relief regions of southern Patagonia, which has led to a widening of the mountain belt during these geologically recent glaciations. This evidence supports the theoretical concept that climate, through erosion, or lack of it, affects the shape and dynamics of mountain belts.

It has long been recognized that Earth's upper crust behaves mechanically like a thick pile of dry sand — that is, as a frictional material in which strength, or resistance to deformation, increases linearly with the confining pressure[2,3]. Under such circumstances, the height and width of mountain belts (orogens) are determined by how efficiently surface erosion acts to balance the rate at which continents collide to create the mountains[4,5]. According to this 'doubly vergent critical wedge theory', all orogenic areas should tend towards a steady state in which the rate of erosion balances the rate of continental convergence on geological timescales of a million years or so. When the rate of one of the two processes changes, this balance is affected and the mountain belt responds mechanically (Fig. 1): if erosion efficiency increases (or decreases), for example in response to climate change, the mountain narrows (or widens)[6,7].

Demonstrating such behaviour in real mountain belts has not been easy — in part because the strong orographic control of precipitation (it rains more on a tall mountain) makes it difficult to say whether climate change is the cause or the result of a change in mountain height (and thus width), and in part because of the incompleteness and imprecision of the geological record. One of the most cited pieces of evidence that climate, through erosion, controls mountain height centres on a measure called the mountain glacier equilibrium line altitude (ELA) as applied to the Andes. The ELA is the altitude at which the rate of snow accumulation is exactly balanced by the rate of ice loss through melting and sublimation; it is also the altitude at which glaciers are most efficient at eroding bedrock. It is now well documented[8] that there is a strong correlation between the ELA at the Last Glacial Maximum and the present-day height of the Andean Cordillera from Colombia to Patagonia. More recently, it has even been suggested that such a correlation exists on a global scale[9].

Interestingly, one of the few places where this correlation does not apply is the southern Patagonian Andes. This is a heavily glaciated area, in which mean elevation increases towards the South Pole, whereas the ELA decreases owing to the extremely cold conditions that existed there at the Last Glacial Maximum and that persist to a lesser degree today. This anomalous topography has been tentatively associated with the subduction of a hot, buoyant mid-ocean ridge beneath South America[10].

To investigate the anomaly, Thomson and co-authors[1] documented the recent erosional history of the Patagonian Andes by low-temperature thermochronology. Their work involved collecting many rock samples (150 or so of them) from between 40° S and 50° S, and dating them by several methods to obtain the time and rate at which the samples cooled on their way to the surface. The authors found that the southernmost samples were systematically older than the others, indicating that they have been eroding, on average, more slowly in the past 5 million years — that is, more or less since the beginning of the recent worldwide periodic glaciations. These older ages do not support the mid-ocean-ridge subduction hypothesis.

From careful field observations, Thomson *et al.* also noted that in the northern regions the width of the Cordillera decreased at the time of glaciation onset, with the cessation of major faulting on either side of the mountain belt. By contrast, in the south, where the authors observe a reduced erosion rate from about 5 million years ago, the zone of active deformation widened over the same time interval. Here, then, is evidence of a clear link between erosion and mountain-belt width (see Fig. 1 of the paper[1] on page 314).

But why would glaciations lead to a reduced erosion rate in the southernmost parts of the Cordillera, whereas elsewhere they have led to intensified erosion? This is the second exciting discovery reported by Thomson and colleagues[1]. Their extensive thermochronological data set supports an idea foreshadowed by numerical modelling[11] — that under extremely cold climatic conditions, such as those prevailing in the southernmost Andes during the Last Glacial Maximum, mountain glaciers do not slide but are frozen to the bedrock. The glaciers thereby protect mountain peaks rather than erode them (Fig. 1).

This work[1] demonstrates a clear connection between varying erosional conditions and the large-scale morphology of one of Earth's major mountain belts. It also shows that the effect of glaciers on topography strongly depends on the temperature at the base of the ice. Overall, the results open new avenues to improve our understanding of the dynamics of mountain belts and the feedbacks that may exist between tectonics and climate.

Using Thomson and colleagues' estimate for the conditions under which glaciers may protect rather than erode mountain belts, we now need to re-evaluate how and when a mountain belt may enter a 'runaway' scenario. This is a situation in which increasing peak heights lead to more extensive glaciated areas where ice is frozen to bedrock, dramatically decreasing mean erosion rate and, ultimately, potentially forming a wide, plateau-like orogenic area such as the Tibetan plateau. The new evidence[1] will also reignite debate on the effects of the long-term cooling of Earth's climate that led to periodic glaciations some 3 million to 5 million years ago, and to their intensification about 1 million years ago: the debate centres on the erosional efficiency of surface processes at these times, and how that has influenced the growth and morphology of mountain belts. ■

Jean Braun is in the Laboratoire de Géodynamique des Chaînes Alpines, Université Joseph Fourier de Grenoble, 38041 Grenoble, Cedex 9, France.
e-mail: jean.braun@ujf-grenoble.fr

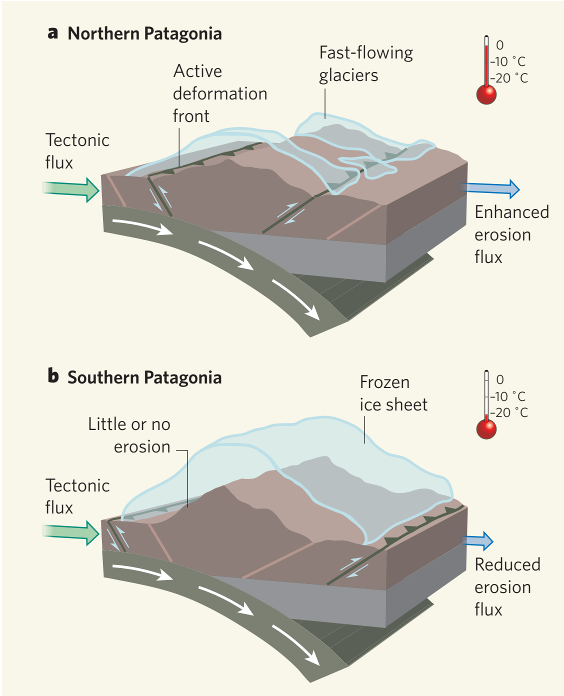

Figure 1 | Tectonics, glaciers and erosion in the Patagonian Andes. Both panels show the balance between the tectonic flux of crustal material into the mountain belt, driven by subduction of the underlying mantle lithosphere, and the erosional flux (flux being the product of the velocity of rocks in or out of the orogen and the corresponding surface area). The differences lie in the differential effects of glacial erosion[1] during periods of extensive ice cover characteristic of the past 3 million to 5 million years. **a**, Northern Patagonia. Here, as indicated by the narrower active deformation front, the mountain belt is narrower because the enhanced erosion efficiency (velocity) caused by fast-flowing glaciers requires a smaller area to balance the same tectonic flux. **b**, Southern Patagonia. In the much colder conditions in the south, the ice sheets are frozen to the bedrock. The result is reduced erosion, and a widening of the mountain belt as the active deformation front moves outwards. (Modified from ref. 12.)

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