TECTONICS

Microplate motion

The fragmentation of continents at convergent plate boundaries is thought to be influenced by the subducting lithosphere. Numerical modelling suggests that instead, the forces exerted by the underlying mantle can drive the formation of continental microplates.

Christine Siddoway

At the juncture between a continental and an oceanic plate at a subduction zone, dense oceanic lithosphere sinks beneath the more buoyant continental lithosphere. The interactions between the plates give rise to a complex interplay of forces that can drive formation of marginal basins and detachment of microplates, which are fragments of the continental plate. These forces are widely thought to arise from changes in the behaviour and mineralogy of the subducting oceanic lithosphere[1]. Writing in *Nature Geoscience*, Rey and Müller[2] show that instead, forces exerted by the buoyancy of the hydrated mantle beneath the overriding continent could be sufficient to cause profound shifts in tectonic activity, leading to fragmentation of the edge of the continental plate.

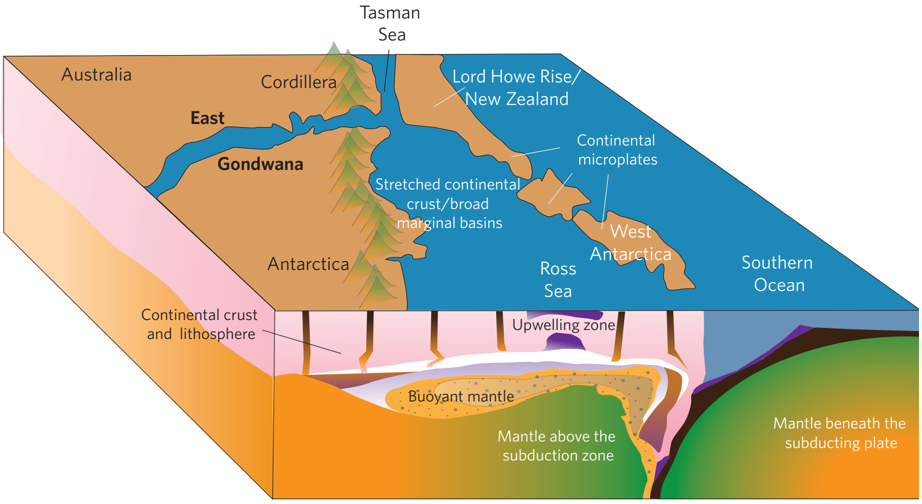

Figure 1 | The formation of microplates at the margin of East Gondwana. About 100 million years ago wide marginal basins formed, and microplates such as West Antartica, New Zealand and Lord Howe Rise (submerged) split off of the margin. Rey and Müller[2] attribute these events to the buoyant rise and lateral spreading of mantle (dotted area) beneath the leading edge of the continent (brown). The material introduced heat and weakened the overlying crust, as it generated lateral forces strong enough to push the oceanic slab (black) and stretch the edge of the continent. Rey and Müller's numerical models show that by this process, vast slices of continental crust — microplates — may be extracted from continents and placed into motion on the global plate-boundary system.

The ancient supercontinent East Gondwana — which consists of present-day Australia, New Zealand and Antarctica — hosted one such subduction zone from 170 to 100 million years ago. However, from about 115 to 90 million years ago, the subduction of the oceanic plate faltered. On the continent, hot metamorphic rocks from deep in the crust were rapidly brought to the surface[3], and volcanism flared up as massive volumes of silica-rich lava were erupted[4]. Eventually, vast marginal basins known as the Tasman Sea and Ross Sea formed, and microplates such as New Zealand and Marie Byrd Land detached from the active margin of the continent.

Rey and Müller[2] used two-dimensional numerical modelling to examine the dynamics controlling similar large-scale processes. In particular, they assessed the rate of tectonic convergence and the density of the mantle surrounding a subduction zone. They show that an increase in the buoyancy of a wedge of mantle overlying the subduction zone — owing to the influx of water and the melting of rocks — causes mantle material to rise and spread laterally beneath the continental plate. This creates resistance at the interface between the upper mantle and lithosphere, a force known as traction. This traction induces the lateral stretching — extension — of the continental plate, which ultimately may result in the opening of ocean basins and the excision of wide slices of the continental crust.

The simulated slices represent continental microplates, which move towards the ocean and exert a lateral force counter to subduction. Astonishingly, the models indicate that the lateral force is sufficient to cause the site of subduction — the trench — to retreat, and the oceanic slab to roll back. This is a provocative finding, in opposition to conventional interpretations in which continental extension is caused by the slab rollback[1], rather than driving it. Moreover, the models predict an array of tectonic and magmatic events across a wide zone of the overriding continental plate in the convergent system.

Rey and Müller compare their simulated sequence of events with the geological record of the active margin of East Gondwana. Beginning about 115 million years ago, the continent underwent complex successions of contraction and extension alongside volcanism on an extraordinary scale[1]. Based on their simulations, Rey and Müller predict that widespread deformation and dramatic thermal anomalies arose from the upward motion of large volumes of hot and viscous material from the mantle and crust (Fig. 1). Their models present a geodynamic context for the crustal processes that may have rapidly transformed a Gondwana orogenic plateau into a broad rift zone[5] fringed by microcontinents.

Depending on the subsequent rate and direction of plate motion, the microplates could remain within the convergent margin system or be transferred to another tectonic plate. For example, the New Zealand microplate now straddles the Pacific–Australian plate boundary; in the future, if these plates separate, portions of the microplate may also diverge, and follow different travel paths on their respective tectonic plates. This demonstrates the manner in which microplates and their associated continental crust move throughout the globe.

Indeed, the genesis of wandering microplates, known as 'exotic' terranes, has baffled geologists for decades[6]. The Tethys Ocean system produced microplates involved in the Alpine collisional zone[7], the Cache Creek terrane[8] and Klamath Mountains province[9] in North America, whereas the Rheic Ocean yielded the continental microplates that now constitute the main part of Central America[10]. Our understanding of both systems could greatly benefit from studies based on Rey and Müller's methods. However, complex systems such the Gondwana margin, where material most likely flowed in and out of the plane simulated by current models[3], can only be fully addressed with the continued refinement and development of three-dimensional modelling.

By examining the role of mantle buoyancy, Rey and Müller[2] have made an innovative foray into a complex realm of continental dynamics, and offered provocative yet plausible explanations for the rapid evolution of some orogenic plate margins. The patterns revealed by their simulations may be used to recognize and interpret microplate formation not only at the East Gondwana margin, but in settings across the globe.

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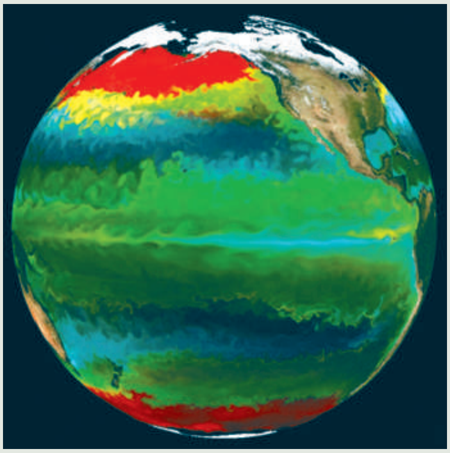
ECOLOGY

Seasons and diversity

Phytoplankton form the foundation of the marine food web. *En masse*, these single-celled organisms take up large quantities of carbon dioxide from the atmosphere and, if not consumed near the surface, deliver it to the bottom of the ocean when they die.

Numerous studies have examined how nutrient levels affect phytoplankton abundance — a primary focus being the impact of iron additions. Less is known, however, about the factors regulating phytoplankton diversity. This is a potentially important omission, as the diversity of these populations could also influence the amount of carbon taken up by the oceans, given that ecosystem diversity is thought to affect function.

Using model simulations, Andrew Barton and colleagues show that phytoplankton diversity should be high in tropical and subtropical waters, as a result of the low seasonal variability at low latitudes (*Science* doi:10.1126/science.1184961; 2010). In their model, biodiversity declines towards the poles as seasonal variability becomes more pronounced. Indeed, observations of many terrestrial and marine organisms, including marine microbes, document such a pattern of declining diversity with increasing latitude.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Seasonal changes in the environment affect phytoplankton diversity via intermittent nutrient supplies. As a result, simulated diversity floundered in temporally changing environments, and those species able to grow fast during high-nutrient periods survived longer than the slow growers. But in the presence of more stable nutrient loads, a diverse community of microorganisms thrived.

The frequency and strength of the oscillation in environmental conditions determined the time it took for species to die out. Multiple species co-existed quite happily for a thousand model-years or more when relatively weak temporal variations were imposed with a period of either years or days — in other words when they mimicked conditions in the tropical and subtropical oceans. But species died off rapidly under the influence of stronger oscillations with a period of months, typical of polar and subpolar waters.

Hotspots of diversity were superimposed on the latitudinal gradient, and coincided with areas of energetic circulation, such as the Gulf Stream. In these regions, ocean currents can replenish depleted phytoplankton stocks, and the continuous mixing of species from different regions probably prevents a single species from becoming locally extinct.

In the simplified model world, phytoplankton diversity is determined in any one location by the balance between the competitive elimination of species and the addition of nearby phytoplankton stocks by ocean currents. The suggestion is plausible, but only a comprehensive ocean survey across latitudes, spanning calm waters as well as locations of vigorous mixing, can confirm the idea.

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