ARCHAEAN CONTINENTAL PLATES

Old and young mantle roots

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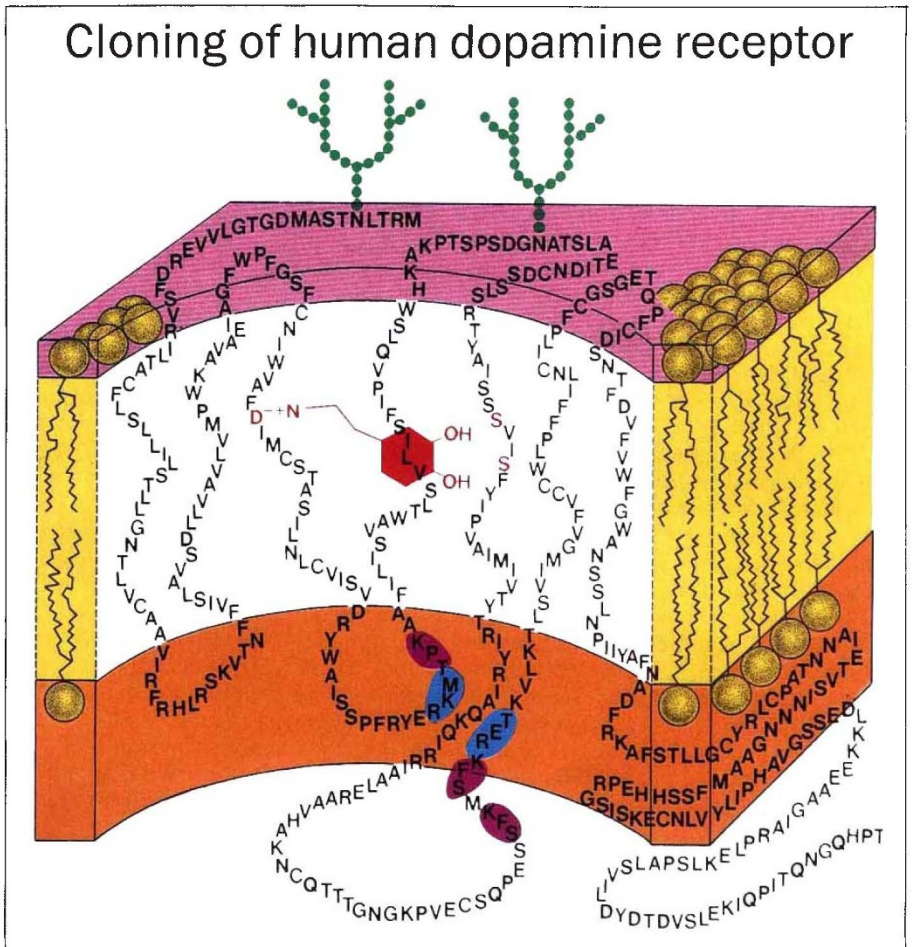
IT is generally believed that the Earth has cooled over the past 4 billion (10^9) years owing to the slow dissipation of the heat originally generated during the planet's growth and the formation of its core, and owing to the decline in internal radioactive heating. But in the absence of empirical constraints, we can specify *a priori* neither the efficiency of heat transfer from the deep interior to the surface (which is related to the form of mantle convection and existence of thermal boundary layers) nor the content and distribution of radionuclides. One way of deducing thermal regimes is by estimating the flexural strength and equivalently the effective elastic thickness of stable continental lithosphere. This thickness corresponds to the temperature-dependent depth of the transition zone above which rocks behave elastically and transmit heat conductively, and below which they deform by power-law creep, fluid-like on geological timescales. By analysing lateral variations in the thickness of ancient sedimentary layers resulting from lithospheric flexure, Grotzinger and Royden demonstrate on page 64 of this issue[1] that the lithosphere in a part of the Canadian shield that stabilized at least 2.5 billion years ago (2.5 Gyr) had an effective elastic thickness at 1.9 Gyr that was almost an order of magnitude less than its estimated[2] present thickness, 100±25 km. This result implies that the thermal gradient has decreased by a factor of 2–4 since, which is consistent with estimates of secular cooling of the Earth. But it is at odds with other indications which have fostered the paradoxical view[3–6] that, despite a presumed high heat flux through the mantle, thick cold roots existed beneath Archaean cratons by 3.2–2.7 Gyr.

If the Earth's mantle were uniform in composition, the limiting thickness of the lithosphere would be the same everywhere. In fact, Archaean cratons (continental areas which have not been significantly stretched or shortened since 2.5 Gyr) appear to have cold mantle roots that extend twice as deep (to about 200 km) as the lithosphere beneath younger continental crust and thermally mature ocean basins. This conclusion is supported by the correlation of Archaean cratons with areas of low surface heat flow[7], high shear-wave velocities[8,9] and high lithospheric flexural rigidities[2]. As emphasized by Jordan[10], the existence of cold mantle roots (tectosphere) implies that Archaean cratons are underlain by anomalous mantle material that is both refractory and of low intrinsic density (to offset its lower temperature). These requirements are met by mantle material that has been depleted in major elements by partial melting[10], an inference strongly supported by the compositions of rock fragments (xenoliths) brought up in volcanic pipes from beneath Archaean cratons[11]. Thus, the depleted roots represent distinct mantle reservoirs that impart characteristic mechanical properties to cratonic plates; they demand genetic explanation.

A key question is whether the mantle roots accumulated progressively (so being thickest beneath the oldest plates) or were a product of unique conditions existing in the Archaean. The latter view has been ascendant. First, it was argued that the estimated Archaean heat flux would have resulted in continuous melting of the continental crust, contrary to geological evidence, were it not protected by refractory mantle roots[3]. In fact the pressure–temperature conditions implied by equilibrium mineral assemblages require no more heat flux to the base of continental



THREE papers in this issue[1–3] report the cloning and expression of the gene that encodes the human D_1 dopamine receptor. Both the D_1 and D_2 receptors are targets of drug therapy in disorders such as Parkinson's disease and schizophrenia. The picture shows[1] that the protein comprises 446 amino-acid residues (single-letter code) arranged in 7 membrane-spanning segments. Dopamine (red) is thought to bind to aspartate (red letter D) and two serine residues (red letter S). The phospholipid bilayer of the cell membrane (yellow) is bounded by the extracellular (pink) and cytoplasmic (orange) aspects. Polysaccharides (green) are attached to glycosylation sites (asparagine residues, letter N). Purple blobs highlight residues thought to be substrates for protein kinase C residues involved with protein kinase A are blue.

The end result of dopamine binding to the D_1 receptor is the activation of adenylyl cyclase, a process mediated by G proteins. The D_2 receptor, in contrast, inhibits adenylyl cyclase. The crucial difference may come from the third cytoplasmic loop and the carboxyl-terminal tail (bottom right). The D_2 receptor has a long loop and a short tail, whereas the D_1 receptor has a short loop and a long tail. This allies the D_1 receptor with the β2-adrenergic receptor, which also works by virtue of its interaction with G proteins. □

1. Dearry, A. *et al. Nature* **347**, 72–76 (1990).
2. Zhou, Q.-Y. *et al. Nature* **347**, 76–80 (1990).
3. Sunahara, R. K. *et al. Nature* **347**, 80–83 (1990).