Earth science

The puzzle of the South Pacific

Norman Sleep

Since the advent of plate-tectonic theory in the 1960s, numerous attempts have been made to find order in the complicated distribution of islands and seamounts in the South Pacific. Progress has been hindered by the remoteness of the region from oceanic institutions, and hence a lack of hard data. On page 479 of this issue[1], Marcia McNutt and her co-workers present high-resolution data from this area which, they believe, runs counter to conventional plume theory.

Most explanations of the distribution of seamounts and oceanic islands have invoked hotspot theory, where a chain of volcanoes is formed as the oceanic plate moves relative to a site of active volcanism caused by an upwelling plume from the mantle (Fig. 1a). The geometry is similar to a series of burns caused by moving your hand slowly over a candle flame, and the expected result is a regular progression in the age of seamounts and islands at increasing distance from the active hotspot.

McNutt's group did not find the expected age progression in their area, a 3° by 3° region in the Cook–Austral chain near the Macdonald seamount. Rather they find three chains of volcanic edifices of which the oldest two were previously unsuspected (see Fig. 1 on page 480). The oldest, the Ngatemato chain, is about 30 million years old, and it erupted on a seafloor that was then 10 million years old; the Taukina chain is slightly younger; and the well-known Macdonald chain has erupted in the past 5 million years.

McNutt's group was able to dredge and date only a limited number of samples. So they used an empirical correlation between gravity anomalies over seamounts and the age of the crust at the time of seamount formation to extrapolate ages over their map area. The physics behind their method is easily understood in terms of seafloor spreading. Oceanic plates diverge at midoceanic ridge axes, and the initially hot material cools from the top down as it moves away from the ridge. The thickness of the cool, strong lid of the plate which floats on the underlying mantle increases with time.

The effect of actual loads on the plate, such as those from seamounts, can be visualized by considering a single point load. Near the ridge where the plate is thin, the load produces a narrow region of large subsidence. Away from the ridge, a broad zone of slight subsidence is produced. The subsidence that a point load would produce is obtained mathematically from the correlation of gravity anomalies and water depth, and is expressed as an equivalent elastic plate thickness. This correlation is frozen in at the time that the seamount forms. (The situation is similar to parking a car on thin ice. A narrow downwarp forms around the car and is frozen in when the ice thickens. The downwarp does not spring back.)

In the case of the McNutt data, there are seamounts of several ages. The equivalent elastic plate obtained for the South Pacific using the actual ages of volcanism is similar to that in the other ocean basins, rather than

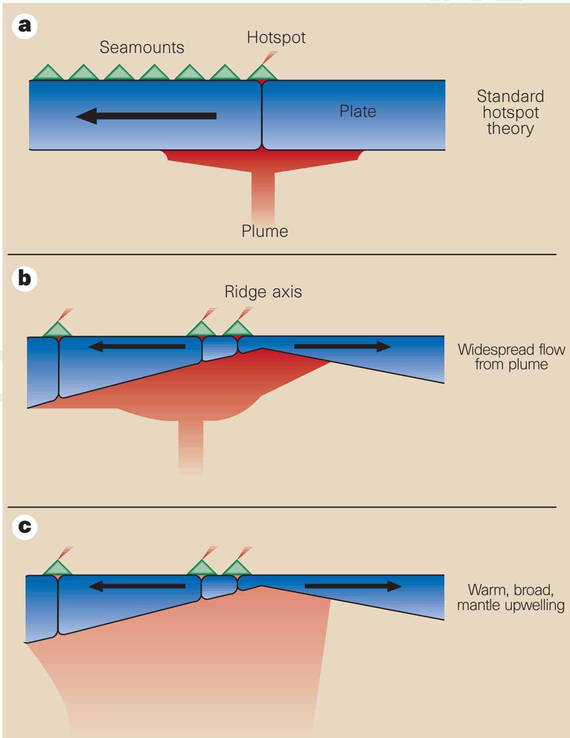
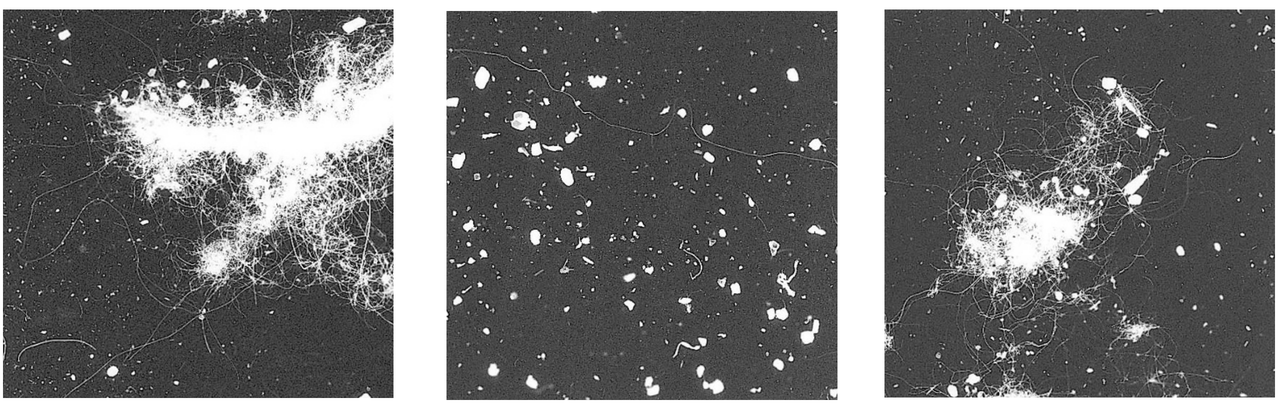


Figure 1 **Standard hotspot theory** (a), **and variations on it** (b, c), **that might explain McNutt and colleagues' data[1] on the Cook–Austral chain of volcanoes in the South Pacific.** c **is the explanation favoured by the authors themselves. Here, a broad region of warm mantle upwelling travels beneath the lithosphere. Cracks in the oceanic plate let magma erupt to form the three chains of volcanic edifices.**

Avoided object

The negatives of sound

Fluff and dust collected from the whispering-gallery, St Paul's Cathedral, London



much thinner as had previously been thought from analysis that assumed only young seamounts existed in the area.

The new information on the ages of the Ngatemato and Taukina chains conflicts with standard hotspot theory. Nonetheless the theory provides a good explanation for the geometry of age progression of other tracks, including Hawaii, and of the volcanic activity of Yellowstone and Iceland. In the South Pacific it may be salvageable by considering the manner in which mantle plumes produce hotspots.

Mantle plumes are supposedly vertical, cylindrical conduits of hot mantle material that ascend from great depths in the Earth, probably from the core–mantle boundary. The plume is 200–300 K hotter than normal mantle, so it is buoyant relative to and less viscous than its surroundings. Lavas for hotspot volcanoes are produced by partial melting at the top of the conduit. The hot material then continues to spread laterally from the conduit along the base of the lithosphere where it may further melt causing volcanism away from the main hotspot. That is, the candle analogy should not be carried too far; plumes are sources of hot material, not point sources of heat.

The older seamount chains studied by McNutt's group were formed near the ridge axis. In this environment, buoyant plume material flows laterally along the base of the lithosphere up to the thin lithosphere at the ridge axis and is dragged away from the ridge axis by the moving plate[2–4]. The net effect is that a broad region of the plate is underlain by plume material and seamounts could form where melts can breach the plate (Fig. 1b). McNutt and colleagues' explanation also involves cracks in the plate that let magmas out, particularly those associated with stresses from seamount loads. However, they favour a broad region of warm mantle upwelling (Fig. 1c) rather than widespread flow from a hot plume.

How does one resolve this issue? There are questions for the dynamicist. Can broad upwelling of warm mantle and hot cylindrical plumes coexist in one convective system? If so, what does this tell us about the Earth? Can plume material from a single source explain the ill-defined tracks associated with the Austral islands? There is work, too, for the geochemical petrologist. Are the source temperatures of volcanism warm or hot and is there a pattern that helps resolve the geometry of flow? All in all, there is much room for more data. In particular, one wonders whether a detailed survey of the whole South Pacific would bring order to the complexity found near Macdonald seamount. □

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2. Ribe, N. *J. Geophys. Res.* **101,** 16195–16204 (1996).
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Evolutionary biology

Pelvic problems for mammals

Robert Presley

Living mammals can be subdivided into the monotremes (which lay eggs), the marsupials (which nurture their young in a pouch) and the placentals (in which the young stay in the uterus until a comparatively late stage of development). Traditionally, the epipubis or so-called 'marsupial bone' has been associated with the suckling of young in a marsupial pouch: its absence from placental mammals supposedly reflected prolonged intrauterine development and birth at a stage when the individual could survive either in a nest or by keeping pace with the mother during lactation.

Now, however, Novacek and colleagues (page 483 of this issue[1]) have identified epipubic bones in fossil mammals which, by all other criteria, would be classed as placentals. Here we have a morphological conundrum.

In their report, Novacek *et al.* describe skeletons from two quite differently specialized mammal groups found in the Late Cretaceous of Mongolia. One is a member of a group known as the asioryctitheres, the other is a zalambdalestid; in both, epipubic bones strikingly similar to those of marsupials are components of the pelvic complex (see Figs 2b and 3b of the paper, page 484). The fossils show a suite of dental and osteological features fitting them into placentals: it is really improbable that they were close relatives of the marsupials. Epipubic bones are also known from a number of other groups of Mesozoic mammals, suggesting that epipubes are primitive features of the mammalian pelvis. From their pelvic build, it seems that the young must have been very small at birth, and it is tempting to suppose that the epipubes are an indication of support of lactating young for a period after birth in which considerable growth took place.

But this is a complicated issue, even when considering living mammals. Monotremes and marsupials have epipubes and also nurse very immature young on a mammary apparatus in the overlying skin. Care is, however, necessary in considering the pouch: echidnas (monotreme) of both sexes have a pouch; but in the platypus (monotreme) neither sex has one; not all marsupial species have a pouch in females, and it is not found in males. So the bone and the pouch cannot be functionally associated in any simple way.

Because males do not lactate, their epipubes cannot be equated with prolonged use of the mammary apparatus. Some workers[2,3], offering something physical for these bones to support, have equated the scrotum, which in marsupials lies in advance of the penis, with the pouch of the female. But this

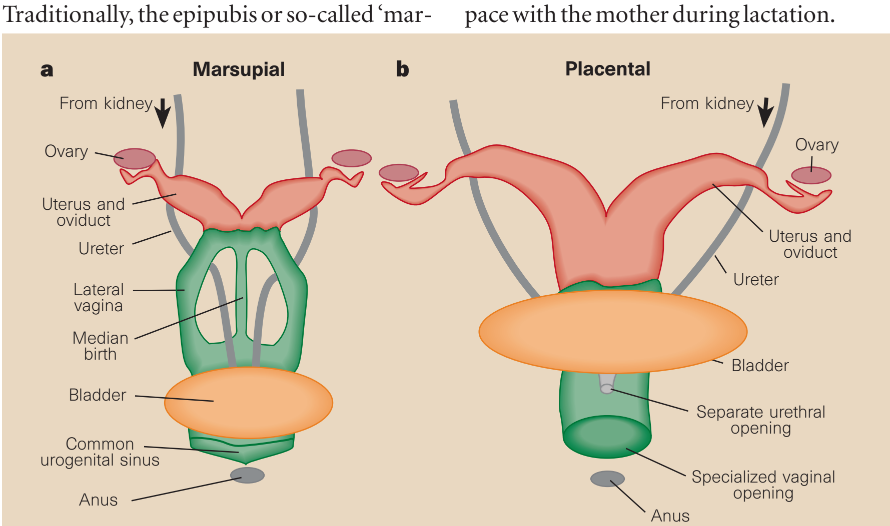

Figure 1 **Ventral views of** (a) **marsupial and** (b) **placental female reproductive tracts, which develop differently in their relations at the urogenital sinus. The basic result in the marsupial is a bladder opening into a common urogenital sinus; twin vaginae lateral to the ureter (metanephric duct) as it reaches the bladder; and a narrow birth canal which is often only patent around the time of birth. The result in placentals is a separate ureteric orifice; a median patent vaginal canal; uteri opening into the vagina (the degree of fusion of the uterine canals varies considerably in placentals). These different anatomies may well have been each set up behind the cover of epipubic bones, which were once regarded as diagnostic of non-placental mammals.**

