GEOSCIENCE

From Earth's Core To African Oil

WASHINGTON, D.C.—Geologist Kevin Burke wants to take plate tectonics down a notch or two. He has nothing against the mechanism, which built the world's great mountains and shaped all the ocean basins. "Plate tectonics is wonderful," he said at a seminar here last month, but "it doesn't do everything." In particular, it needs help to explain Africa, a continent nearly untouched by other drifting plates for 200 million years. African geology, Burke argues, is shaped not by the clashing and grinding of plates but by plumes of hot rock, some of which rise 2900 kilometers from Earth's molten core. He sees a chain of events leading to Africa's corrugated surface and ultimately the oil riches being harvested offshore of Nigeria, with the origin of humans in midchain for good measure.

Some researchers are quick to challenge one link or another in his chain—"he's certainly stirring the pot," says seismologist Andrew Nyblade of Pennsylvania State University, University Park. But Burke's approach of linking the geological record at the surface with the increasingly detailed seismic snapshots of the deep Earth is an emerging new direction in the geosciences.

Bridging the gulf between geology and geophysics can appear presumptuous, and Burke, of the University of Houston, is not at all the shy sort. "I don't measure anything," he said, "so I like to take other people's data and ask, 'What could it mean?' The trouble is the African story is very elaborate, and it's not close to what you'd call the mainstream."

Burke, who laid out the latest developments in his unorthodox scenario at the Carnegie Institution of Washington seminar here, begins with the widely recognized observation that "Africa hasn't moved much with respect to the mantle beneath it" for 200 million years. In fact, "it hasn't moved at all in the past 30 million years." Africa just doesn't have much get up and go, because it lacks the cold, dense slabs of sinking ocean plate found off Japan and South America. There, as the slabs sink into the mantle, they exert a powerful pull on the plates to which they are attached. In contrast, the African plate—the continent and its surrounding ocean crust—is bounded on nearly all sides by midocean ridges that push against it only gently as new crust spreads away from the ridges. Africa's dearth of slabs also means there's long been no cold "downdraft" of slabs into the deep mantle beneath the continent; without such refrigeration, the mantle beneath Africa has been heating slowly, most researchers believe.

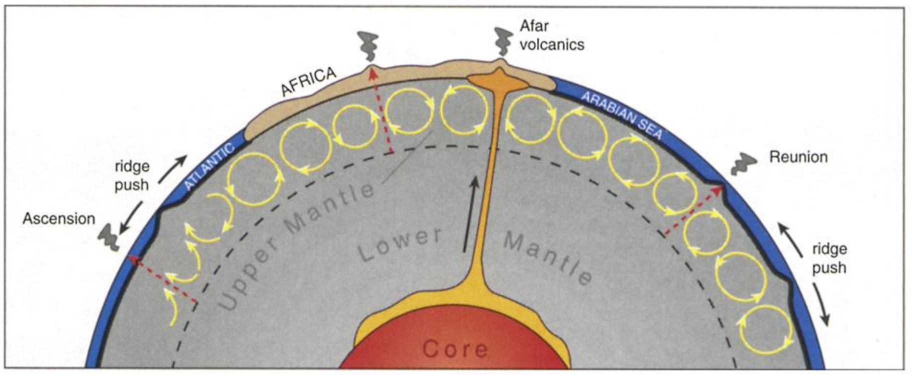
By running the plate tectonics machine backward (mathematically) for 250 million years, Burke thinks he has traced a major force in African geology back to this deep heating of the mantle. During the past 250 million years, there have been 29 massive lava outpourings around the world, called large igneous provinces (LIPs). Many researchers believe LIPs mark the spot where rising plumes of hot rock hit the bottom of a plate, melt a bit of it, and send magma upward to gush onto the surface in a rare "flood basalt" eruption.

When Burke recently backtracked from the present position of each LIP—such as the Siberian Traps—through its past plate motion to its position at formation, he found that 25 of the 26 LIPs that could be analyzed had formed over one of two regions: the Pacific Ocean or Africa. As it happens, those are the same two regions where seismic probing has in recent years revealed two great blobs of hot rock—often called superplumes—sitting on the bottom of the mantle hard against the core (*Science*, 9 July 1999, p. 187). The coincidence, says Burke, suggests that the African blob has been down there at least 250 million years, episodically sending plumes toward the surface.

It was one of those episodic plumes that set the geologic style of Africa for the past 30 million years, according to Burke. Before 30 million years ago, the African continent was fairly flat and low-lying. Things had been quiet geologically for many tens of millions of years. Then a large plume rose beneath what is now Ethiopia, lifting the plate into a 1000-kilometer-wide dome and spewing the Afar LIP. At about the same time, Africa came to a dead stop. As Burke sees it, the weak push from the midocean ridges simply couldn't drive the African plate over the new plume-raised "hill," pinning the plate where it was.

Pinning the African plate was key to Africa's subsequent geologic history, says Burke, especially aspects of interest to us humans. It allowed the Afar plume to work on the same spot for tens of millions of years, tearing open the Red Sea, the Gulf of Aden, and the East African Rift. The latter seems to have been an environmentally benign cradle for the evolution of early humans.

The plate standstill also allowed the mantle beneath the African plate to switch its style of heat-driven circulation, Burke thinks. Instead of flowing in one broad cell that slowly rises on one end and falls on the other, the upper mantle's convective circulation broke up into a field of small cells, like so many pots of boiling water. That's what computer simulations call for when a plate stops moving, notes Burke, and he can see evidence of the convection rippling beneath the surface in the more than 30 swells of higher ground it raises across the continent with basins between. Most of the swells are capped by volcanoes, fed by shallow plumes, he presumes. Erosion of the swells, especially in central and northern Africa, then carried sediments offshore, where they buried organic-rich sediments related to a previous plume episode, giving rise to the oil that enriches the Niger delta and Congo deep-sea fan.



The core's long reach. In Kevin Burke's scheme of African geology, the lack of cold, descending slabs allows hot, ascending plumes to shape the surface.

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Support for Burke's grand story in the geophysics community is mixed. Bradford Hager of the Massachusetts Institute of Technology "would quibble with the details" of Burke's plate-pinning plume but finds it reasonable, "crudely speaking." Gregory Houseman of the University of Leeds, U.K., who did some of the early computer simulations of shallow mantle convection, also believes there is small-scale convection beneath Africa. But seismologists who are beginning seismic surveys of the mantle beneath Africa can't see most of what Burke envisions. "There's no sign of small-scale convection" in the upper mantle, says Paul Silver of Carnegie's Department of Terrestrial Magnetism.

Burke is undismayed. He sees further tests coming in the ongoing expansion of African mantle seismic imaging and better dating of events in his plate-pinning scenario. Then maybe plume tectonics will erupt into acceptance. **—RICHARD A. KERR**