Questioning mantle plumes

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in 1850, after several years in Cuba. Through a sequence of implausible accidents that started with his attempts to treat headaches using electricity, he developed from scratch a true and complete telephone system between 1849 and 1870. He made the first complete prototype in 1856 and used it to communicate with his disabled wife: His laboratory was in the basement and she was in seclusion on the upper floor. His invention, which he called a "telettrofono," led to the fabrication and operation of a small functioning but short-lived telephone network in his village of Clifton in Staten Island, New York. In the 1850s he also developed a working microphone and a process to produce adequate electrical copper wires.

In the following years, Meucci relentlessly sought investors to commercially develop his invention; to that end he delivered a complete set of blueprints and prototypes to American District Telegraph, with which Bell was connected. Later, when Meucci requested the return of the papers, ADT officials claimed they had gone missing.

Meucci established a company that in December 1871 filed for a caveat—a one-year provisional patent—because he did not have enough money for a full patent application. In July 1871 he had been severely injured during the fire on the *Westfield* ferry in New York Harbor and was hospitalized for several months. His impoverished wife had to sell off even the prototype telephone samples for the sum of $6. Bell filed his patent application in 1876 and had it granted. Meucci fought Bell's patent in the courts for many years, but he lacked the financial resources to confront the powerful Bell Telephone Co. He was defeated in what many consider an unjust and corrupt trial. The case was "discontinued as moot," and the matter legally unresolved, because of his death and the expiration of Bell's patent.

The history outlined here is amply documented at, for example, the Garibaldi–Meucci Museum—Meucci's former home in Staten Island. In Italy, Meucci is acknowledged as the inventor of the telephone, regardless of who the patentee may have been. In 2002 the US Congress recognized his role with House Resolution 269 (http://www.gpo.gov/fdsys/pkg/BILLS-107hres269ih/pdf/BILLS-107hres269ih.pdf).

The Meucci versus Bell versus Gray affair clearly demonstrates how, for centuries, the patent legal system in the US and elsewhere, far from protecting the rights of individual inventors and promoting innovation, has served the interests of well-organized, capital-backed corporations. The new direction for the patent system—"first to file" rather than "first to invent"—can only exacerbate the wrong.

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■ **Boucher replies:** Roberto Molteni's interesting discussion highlights weaknesses in the patent system that few fail to acknowledge. But the full history surrounding the various claims—set forth in some 600 legal cases—over who invented the telephone distorts a fuller objective evaluation of the merits of patent systems. That history is unusually rife with allegations of fraud—including against Antonio Meucci, who was accused of backdating his own records in an attempt to predate Alexander Graham Bell—and of conflicts of interest and intellectual theft.

Meucci's caveat highlights pitfalls that still exist for inventors, particularly those who rely on provisional applications with incomplete descriptions. Critics have pointed to relevant omissions—notably the lack of any meaningful disclosure of converting sound to variable electrical conduction or vice versa—that continue to drive the debate over who invented the telephone. Even House Resolution 269, while attempting to bring a measure of appropriate recognition to Meucci's role, avoids an unambiguous assertion that he invented the telephone. Rather, it states that "if Meucci had been able to pay the $10 fee to maintain [his] caveat after 1874, no patent could have been issued to Bell." That statement pertains most precisely to the caveat's potential impact as prior art to Bell's specific patent claims.

Molteni's criticisms have merit, even if I do not fully agree that the patent system fails to protect the rights of individual inventors. The US decision to transition to a first-inventor-to-file system reflects a political judgment that favors greater certainty and increased harmonization with the world's other patent systems. But like all political judgments, it is not without its flaws.

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Questioning mantle plumes

Upon reading "Looking for mantle plumes" by Eugene Humphreys and Brandon Schmandt (PHYSICS TODAY, August 2011, page 34), I had a déjà vu moment. The first part was very familiar. It is based on laboratory fluid-injection experiments of the 1980s, the 1988 Cambridge thin-plate-geotherm model, and geochemical papers of the time.[1] (The 1988 model has been abandoned by Cambridge seismologists and is not supported by data or by realistic simulations.) Thermodynamics, self-compression (gravity), secular cooling, radioactivity, and contemporaneous geophysics were ignored, as noted at the time.[2] The model favored in the 1980s required a homogeneous, unheated, adiabatic, melt-free upper mantle and a primordial gas-rich lower mantle and relied on simulations that were unscaled for size, pressure, and gravity.[1] Plate-tectonic and upper-mantle boundary-layer mechanisms were discounted ab initio. Physics, which fundamentally rules out narrow upwellings in an internally heated Earth-size planet,[3] was not a consideration, as is apparent in the figures of the PHYSICS TODAY article.

Although mantle plume hypotheses are moving targets, the one adopted is particularly out of date.[4] The thin-plate geotherm in the article's figure 2 does not explain the low-velocity zone, anisotropy, absolute wave speeds, and vertical gradients of wave speeds. Geophysical and tectonic models that take into account the neglected physics tell a different story,[2,3] as do newer USArray data and plate-tectonic reconstructions[5] (four-dimensional tomography). Red blobs in relative tomography apparently are slab gaps and ambient mantle, not hot plumes. The unphysical scaling assumptions (red equals hot upwelling) plus the 1988 homogeneity and thin-plate assumptions[1] implied that Yellowstone could not have a plausible tectonic, nonplume, or shallow-mantle explanation as most continental hotspots do.[6]

Geophysical modeling produces large-scale subadiabatic structures in the deep mantle that are typical of normal internally heated planetary convection, a mode that the original mantle plume hypothesis was intended to replace. Well-constrained seismic inversions invariably produce a thick (220-km) anisotropic, heterogeneous boundary layer, which violates the thin-plate and ambient-mantle assumptions and explains why some seismic experiments apparently image near-vertical streaks under the array.[3] Significantly, sources deep within that layer satisfy thermodynamically constrained petrological data and, as J. Tuzo Wilson pointed out in 1963, are fixed enough to create volcanic chains.

A hypothesis needs to be challenged if it violates physics and thermodynamics. Plume hypotheses are too ill-defined and flexible[1,4] to be tested, but scaling relations and assumptions can be. There has not been a recent physically based critique of the hypothesis. However, boundary layer physics; the effects of radioactivity, pressure, and secular cooling on the geotherm and on mantle dynamics; and the effects of anelasticity, anharmonicity, and anisotropy on Earth models and on the interpretation of tomography indicate that apparent sightings of plumes are not based on data or theory. They are instead the result of the unphysical assumptions and nonunique interpretations of data such as *relative* near-vertical travel times. Studies that address fundamental problems in mantle and planetary physics[2,3] usually ignore the plume hypothesis and will not appear in searches for mantle plumes, but they make a strong case against narrowly focused and spontaneous deep upwellings (not imposed by unnatural boundary conditions that violate the second law) being responsible for surface volcanoes.

Implications of such studies[3] include the following:

▶ The geotherm of the mantle sampled at ridges is not representative of ambient mantle.

▶ When the conductive gradient shown in the article's figure 2b is extended to depths required by surface waves, temperatures are hundreds of degrees hotter than shown.

▶ Ambient mantle, from midplate geophysical and petrological data, is 150–200 K hotter than assumed in thin-plate models.[1]

▶ The global low-velocity zone contains 1–2% melt, on average.

▶ Thermodynamically consistent subplate geotherms are subadiabatic and 300 K colder at lower mantle depths than assumed; that makes plumes, if they exist, useless for providing excess temperatures.

The effects of compression, secular cooling and anisotropy, and properly scaled simulations eliminate mantle plumes as an observational fact or a viable physical theory.[3] The physics-based and surface-wave-based plume alternative is simply this: Midplate volcanoes tap into a thick sheared anisotropic boundary layer that is sufficiently hot, fertile, large, and fixed, at depth, to explain volcanic chains; the layer is disrupted at ridges.[3,4]

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Low-energy tools underlie high-energy physics

Charles Roos (PHYSICS TODAY, May 2012, page 10) has charged me with naiveté in claiming that high-energy particle physics has never produced jobs for anyone but HEP physicists (PHYSICS TODAY, September 2011, page 10). In support of his charge he cites several developments stemming from HEP research that have contributed significantly to the economy and to job growth.

However, Roos appears to have inadvertently made my case for me: None of the contributions he cites has anything to do with HEP physics itself. All are tools engineered from lower-energy electron-volt physics, or byproduct results, or spinoffs. High-field and superconducting magnets are pure eV physics. Money spent on the thousands of them in the Large Hadron Collider at CERN would have benefited the country and the world more if the funds had instead been spent on developing superconducting transmission lines to convey electricity efficiently from the remote solar and wind farms generating it to urban centers using it.

All R&D programs generate unexpected byproduct results or spinoffs. That is an excellent reason for public support of science: You always get lagniappe—more than you paid for. However, the unpredictability of those results means that the expectation of them cannot be the basis for choosing to support one program over another. For example, the development of integrated-circuit microprocessors was greatly speeded by NASA's need for extremely lightweight computers in triplicate for its space capsules. So the entire computer industry—for smartphones, cars, washing machines, and refrigerators—can be claimed to be a byproduct of the space program. Millions of jobs! (Memo to NASA: Ask for more money.)

All the jobs for which Roos credits HEP physics are applications of eV physics and result merely from the expenditure of vast sums of money, irrespective of the goal for which it was spent. They have nothing to do with HEP physics itself.

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