letters

A broader picture of Rutherford's geophysicists

In his interesting article "Rutherford's Geophysicists" (PHYSICS TODAY, July 2010, page 42), Greg Good says, "Rutherford and others believed that the heat given off by radioactive elements derailed the arguments that Lord Kelvin had used to support a youthful Earth and to critique Charles Darwin's theory of evolution by natural selection." Given that this belief undoubtedly influenced the development of geophysics, I find it interesting that the primary error in Kelvin's estimate was not his neglect of a heat source but rather his neglect of any means other than conduction for getting heat out of Earth. Indeed, if Earth had zero radiogenic heat sources, it would very likely convect, slowly eliminating the great heat produced from gravity when the planet formed. Kelvin's tens of millions of years—roughly the typical age of the ocean floor—would still be a reasonable estimate for the conductive diffusion time of heat through the thermal boundary layer. This is not something related to Earth's total age, because the mantle has overturned many times in Earth history.

At the time Kelvin proposed his argument, the fact that much of Earth is solid had not yet been well established. Therefore, the idea that Earth's deep interior convected was not unreasonable, and later arguments about the ability of solids to flow would not have been a problem. He could have obtained a roughly correct answer for Earth's age by merely dividing the planet's total heat content by its total heat output; that calculation yields around 10 billion years for current estimates of the input numbers, and it would have been a perfectly reasonable thing to do for the understanding of cosmogony at that time. Of course, Kelvin had the misfortune to get a similar answer for the Sun's age as he obtained for Earth; the method he used roughly works for Earth but fails badly for the Sun because he was understandably unaware of fusion.

Another great scientist, Harold Urey, is responsible for posing the question of how much of Earth's heat flow comes from radiogenic heat production rather than secular cooling. The current estimate for the fraction derived from radiogenic heating is around one-half; the reason for that value is still hotly debated.

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As one who knew both Edward "Teddy" Bullard and one of Patrick Blackett's doctoral students in paleomagnetism, I read with great interest "Rutherford's Geophysicists" by Greg Good. I am concerned, though, that the article suggests, even if inadvertently, that Bullard was the first to propose electrical currents in Earth's liquid-metal core as being capable of sustaining the geomagnetic field by dynamo action and that his March 1948 paper[1] contained a dynamo model.

That paper makes no mention of the first suggestion, by Joseph Larmor in 1919, that Earth's magnetic field might be maintained by something like a dynamo in its interior.[2] In a footnote in his 1948 paper (page 249), Bullard acknowledged the prior and "similar" arguments by Walter Elsasser in his two 1946 papers, but strangely does not mention Elsasser's important 1947 paper on the toroidal field modes.[3] Elsasser's papers discuss at length the mathematical representation of the poloidal and toroidal parts of the geomagnetic field and the dynamics and energetics of the feedback mechanisms necessary to sustain it. But Bullard's March 1948 paper concentrates on the secular variation rather than on dynamo action and offers only the briefest summary of possible causes of motions in the core. In fact, the first of Bullard's many papers on geomagnetic dynamo models[4] was not submitted for publication until November 1948. That paper concludes with his generous acknowledgment of the influence of Elsasser's work on his own ideas.

My comments are not intended to detract from Bullard's extensive and original contributions to geomagnetic dynamo theory, only to remind readers that Elsasser did foundational work at a time when the origin of Earth's magnetism still appeared to be a nearly impenetrable mystery.

References

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3. W. Elsasser, *Phys. Rev.* **69**, 106 (1946); **70**, 202 (1946); **72**, 821 (1947).
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Having read Greg Good's excellent article, I must take issue with the statement, "Like many English children, [Bullard] attended boarding school." Although the image of boarding schools, from Tom Brown's school days to Harry Potter's, is common in English literature, the reality is that only a privileged few have attended such institutions. One wonders whether Bullard's genius would have been nurtured and recognized had he not had the advantage of a private education at a time when most children left school at an early age with only the basics.

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Greg Good's fascinating article compares the careers of two geophysicists,

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