COMMENT AND REPLY

John Perry's neglected critique of Kelvin's age for the Earth: A missed opportunity in geodynamics, Philip England, Peter Molnar, and Frank Richter, *GSA Today*, v. 17, no. 1, p. 4–9, doi: 10.1130/GSAT01701A.1.

Comment

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In touting John Perry, England et al. (2007) misrepresent modern and historical efforts to understand Earth's cooling.

Perry promulgated Kelvin's fundamental error of using equations inappropriate for cooling of a large, finite sphere. Both plate and Kelvin-type models contain unrealistic boundary conditions and inputs (Hofmeister and Criss, 2005, 2006). Perry used a surface temperature (T) of 146 °C and interior thermal conductivity (k) 79 times crustal k . By comparing cooling of a homogeneous infinite half-space to a thin spherical shell, Perry deduced that high interior k slows cooling.

England et al. agree and link high interior k to mantle convection. In contrast, high k makes conduction efficient (Lubimova, 1958) and convection unnecessary. Time-dependent convection models (van den Berg et al., 2004) show low upper mantle k retards cooling. Geodynamic research requested by England et al. exists and shows them wrong.

England et al. cite secondary, outdated sources for high k . Suspicious upturns giving high vibrational k at high T are proven experimental artifacts (Pertermann and Hofmeister, 2006). Radiative diffusion in Earth's mantle cannot provide

high k (Preston, 1956; Hofmeister, 2005). Consequently, deep interior k resembles surface values (Hofmeister, 1999).

Likewise, 20 TW for Earth's radioactive heat generation is neither modern nor correctly attributed. Chondritic models reconcile heat flow data with radioactivity within uncertainties (Urey, 1956; Hofmeister and Criss, 2005).

Kelvin's famous calculations, coupled with denial of observational data, impeded geoscience for ~100 yr. It is a shame to see data ignored and Perry lionized given his statement "I dislike very much to consider any quantitative problem set by a geologist."

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Reply

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In touting their views, Hofmeister and Criss (2007) misrepresent what we wrote, what Perry wrote, and some simple aspects of heat transfer.

Hofmeister and Criss accuse Perry of deducing that high interior thermal conductivity slows cooling of the Earth and us of agreeing with that deduction. Neither accusation is correct. Perry showed that higher interior conductivity would quicken cooling of the Earth, thereby making the present surface heat flux compatible with a much greater age than Kelvin calculated; we agree with Perry.

Hofmeister and Criss appear to believe that high conductivity makes convection unnecessary. Even were this belief correct, which it is not, it would be a non sequitur; our purpose was to draw attention to Perry's contention that convection in the Earth's interior can be modeled by a high "quasi-conductivity." They write that we requested geodynamic research on this topic. We did not, because high-Prandtl-number convection has been understood for decades; there is no need for complicated models. Convection can maintain the Earth's surface heat flux at its observed level for gigayears, whereas thermal diffusion cannot. Hofmeister and Criss join Kelvin in missing this point.

Equally, their arguments about radiogenic heating in the Earth's deep interior are irrelevant because its influence on Kel-

vin's calculation is utterly negligible with the value we adopt, and two-thirds as negligible with the value they prefer.

Hofmeister and Criss write that we cite "secondary, outdated sources" for measurements of thermal conductivity. We cite no source at all for such measurements, not even theirs, because they are not relevant to our arguments. Perhaps they were confused by our remark that Perry's "quasi-conductivity" could be expressed in modern terms by the Nusselt number. However, even a superficial reading of the works we cite in this context would have revealed that they concern convection, not conduction.

Their final paragraph is purely rhetorical. Kelvin did not ignore observations; indeed, his attempts to use observations to constrain the age of the Earth forced geologists to abandon their reckless drafts on the bank of time. Hofmeister and Criss's dismissal of this history as Kelvin's "impeding geoscience for ~100 years" is not supported by serious work on the matter. Furthermore, their attack on Perry shows a complete misunderstanding of a modest and conciliatory person. Perry's reluctance "to consider any quantitative problem set by a geologist" should be taken as an expression of qualms about his ability to combine geology and physics, not as hubris.

We should like to take this opportunity of directing the interested reader to Shipley (2001), who provides an excellent description of the background to Perry's exchanges with Kelvin in 1894–1895.

Thanks to Patrick Wyse Jackson for drawing Shipley (2001) to our attention and Norman Sleep for supportive comments.

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