BURKE'S LAW: TOWARD A REASONED DISCUSSION OF DEEP TIME

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Physical scientists generally believe we can never prove something to be true, but only falsify hypothetical propositions. In a data-rich environment, we would ideally specify null and alternative hypotheses and test the statistical significance of both. But those studying deep geologic time are limited by a profoundly incomplete rock record that itself may reflect significant preservation biases. Popper (1945) argued that "while the theoretical sciences are mainly interested in finding and testing universal laws, the historical sciences take all kinds of universal laws for granted and are mainly interested in finding and testing singular statements." This is hardly a condemnation of historical geology; one does not study the Archean to prove quantum mechanics, but rather to constrain conceptual models based on physical laws assumed to be constant through time. Thus, testing concepts regarding ancient Earth requires different rules adapted to the paucity and type of evidence available. In the course of these authors' careers, recognition dawned that there is little or no agreement on what those rules should be. In its absence, an ad hoc set of assumptions was adopted, many of which have a poor foundation in reasoning and tend to inhibit actual model testing. Loosely phrased, one such custom is: if we do not see preserved evidence of a process in the rock record, it did not occur (e.g., Taylor and McLennan 1995, 2009; Brown 2006), and its corollary, if you do not see explicit evidence of past mobile lid activity, plate tectonics was not operating (e.g., Condie 2015). Reflecting our opposition to this view, we refer to the latter as the self-affirming, non-mobile lid misconception (or, awkwardly, SANMLM).

Our purpose is not to insist that mobile lid tectonics was operating in the distant past, but instead to ask our community to hold itself to a higher standard when claiming that it was not.

Where can we seek advice for such rule making? In our view, the philosophy of science literature offers little guidance to historical geology as it is largely a retrospective linearization of the history of physics. While one could argue that reductionism implies that all sciences eventually condense to a form of physics, this immediately leads to the ontological conundrum described by Baker (1999). Of the enabling sciences, biology would seem a better source of instruction, given its similar grounding in an evolutionary context, but actions on its behalf appear to us more cautionary than helpful. For example, the International Code of Nomenclature of Bacteria (Lapage et al. 1992) presents seven general considerations, nine principles, and 65 rules to establish a "precise system of nomenclature accepted by the majority of bacteriologists of all nations." However, it also includes the proviso that "Definitions of the taxonomic categories will inevitably vary with individual opinion…" (Rule 5a). Can we do better?

Plate tectonics erases much of the primary evidence of its past existence (i.e., subducted oceanic lithosphere) and works to erase secondary evidence (e.g., paired metamorphic belts). The question then becomes: does it leave any evidence of its past operation? In response to this uncertainty, the late geologist Kevin Burke's (see Şengör, 2018) oral rejoinder to SANMLM was a uniformitarian statement we informally refer to as Burke's Law: *If there's unambiguous evidence that global geodynamics is today dominated by plate tectonics, then we should assume it was operating since global silicate differentiation until we have evidence that it was not*. While this statement fuses two longstanding scientific truisms—"absence of evidence is not evidence of absence" (https://quoteinvestigator.com/2019/09/17/absence/) and Occam's razor (i.e., simpler is better) —neither necessarily apply to all scientific problems.

While it is not universally true that "you can't prove a negative" (e.g., Hales 2005), the "absence of evidence is not evidence of absence" aphorism seems on solid semantic ground in our context given the universally agreed role that plate tectonics plays in consuming most evidence of its action. Despite its aesthetic appeal, Occam's razor can be an imperfect guide in the life and historical sciences (e.g., Crick 1988) and requires further justification. There is no basis to assume that Earth, a collection of non-linear systems at all scales, should always be parsimonious with its evolutionary trajectory. It is important, however, to keep in mind that the practical value of Occam's razor is not about getting at some absolute truth, i.e., the true manner in which the Earth evolved. It is, instead, about determining which hypothesis, given that many may be able to fit data (especially incomplete data with uncertainty), is more likely correct given the observations at hand at any given time. This connects Occam's razor to Bayesian methods of hypothesis discrimination and/or model selection. Bayesian analysis will favor the less complex hypothesis/model (MacKay 1992). This is because as models—be they conceptual or quantitative—become more complex, with more free parameters and/or imperfectly understood processes, they also become more difficult to refute, and Bayesian analysis gives weight to models that are more refutable. Plate tectonics as a hypothesis/model is not simple in an absolute sense, but it is simpler than any hypothesis/model that invokes tectonic transitions over Earth history ("The onus of proof is always on the advocate of the more complicated hypothesis"; Jeffreys 1961). Recall that an essential aspect of Occam's razor is to not complicate beyond necessity the particular question/issue being addressed. It is not a criterion of absolute simplicity but of relative simplicity (the simplest model for one field may be complex relative to that for another field). This is our essential rational for arguing that the base-level tectonic evolution model, the null to be disproved before more complex models are invoked, is continuous plate tectonics.

Our purpose is not to insist that mobile lid tectonics was operating in the distant past, but instead to ask our community to hold itself to a higher standard when claiming that it was not. Thus, our support of Burke's Law is only part of the necessary analysis. We need to examine the epistemic basis for any claim of knowledge of Earth behavior in deep time. If classical hypothesis tests regarding ancient Earth require different rules adapted to the paucity and type of evidence available, then it is incumbent on our community to create and promulgate them.

While, as reasoned above, Burke's Law has a discernable intellectual foundation (albeit as a modern reformulation of the 19th-century concept of Uniformitarianism), SANMLM violates Hume's Law (Şengör 2001) and is less an identifiable philosophic position than it is a sociologic one. In the extreme, some authors have characterized notions of early continental crust or plate-tectonic-like activity in imaginary or fictitious terms. Taylor and McLennan (1995) went as far as to write "No good evidence exists for that enduring geological myth of a primordial world-encircling crust of sial or granite," later referring to "The early continental crustal myth" (Taylor and MacLennan 2009). Given that "myth" is generally understood to be a widely held but false belief or idea, the standard of evidence for invoking such a claim should be extremely high and yet no smoking gun evidence in support of their view exists (or possibly could, given the lack of a >4 Ga macroscopic rock record). Alternatively, others simply aver knowledge of ancient geodynamic transitions, even in the face of conflicting evidence (e.g., "No one

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method should be used to identify ancient tectonic settings, and this is especially true for rocks older than 2.5 Ga, when Earth was changing from stagnant lid to plate tectonics"; Condie 2015).

Perhaps the most remarkable aspect of these practices is that, as widely as they have been practiced over several decades, they appear to not have heretofore attracted significant criticism or complaint. That said, we are aware of some prior constructive arguments (e.g., large-scale, direct evidence should take precedence over small-scale, circumstantial evidence; Stern 2016) that could seed community action toward a framework in which discussions free of arbitrary judgements of deep time can take place. To that, we add 10 of our own suggestions that could provide a common basis for addressing geodynamic questions of deep time. These are:

1) Explicitly acknowledge where proposed multi-stage evolutionary scenarios are functionally untestable;

2) Ensure that alternate published explanations and evidence are documented in a scholarly manner;

3) Distinguish hypothesis/model consistency from uniqueness; limit use of "hypothesis" to realistically testable models (suggest using "heuristic" otherwise);

4) When testing quantitative models against observations, perform global uncertainty analyses accounting for observational and model uncertainties;

5) Qualify limits on global interpretations from a single region or outcrop;

6) Avoid characterizing viable alternate hypotheses as fictitious or mythologic;

7) Avoid claims of fact regarding timing of geologic transitions that remain ambiguous;

8) Acknowledge that major changes in global tectonics may have required extended transitions;

9) Test proposed tectonic transitions by exploring expected consequences (to true polar wander, climate, life, etc.); and

10) Avoid terminology in public outreach implying final resolution of deep time issues under ongoing debate.

While the above checklist is proposed with early Earth debates in mind, we note that most would be expected to also apply to current discussions of long-term climate change. We of course welcome constructive criticism of our own ideas, both those expressed in this article and beyond, as well as proposals for a venue in which to gather community feedback and continue this discussion.

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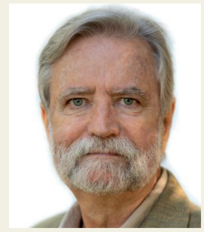

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