



It's Time to Defuse the Cambrian "Explosion"

Jacob Beasecker, Zach Chamberlin, Nicole Lane, Katie Reynolds, Jack Stack, Kailey Wahrer, Abigail Wolff, Dept. of Earth & Environmental Sciences, Michigan State University, East Lansing, Michigan 48824, USA; Jo Devilbiss, Corey Wahr, Dept. of Integrative Biology, Michigan State University, East Lansing, Michigan 48824, USA; Dan Durbin, Hannah Garneau, Dept. of Fisheries & Wildlife, Michigan State University, East Lansing, Michigan 48824, USA; and Danita Brandt, Dept. of Earth & Environmental Sciences, Michigan State University, East Lansing, Michigan 48824, USA

Volcanoes may erupt explosively. Meteoroids may explode on entering the atmosphere. A microwaved grape may explode (Conover, 2019). However, a growing body of research suggests that biodiversity at the dawn of the Cambrian Period did *not* explode. Data, amassed in the century and a half since Charles Darwin (1859) agonized that the apparent absence of Precambrian lifeforms was the weakest link in his theory of evolution by natural selection, support the view that biological diversity at the beginning of the Cambrian Period did not burst violently, detonate, shatter, or blow up. In this contribution, we trace the origin of the phrase “Cambrian explosion,” give reasons for moving away from using it, and offer an alternative for describing intervals of significant increase in the diversity of life.

The bibliographic pedigree of the phrase “Cambrian explosion” is uncertain; its origin is not clearly established in peer-reviewed literature. By the early twentieth century, the abrupt appearance of abundant (macro-) fossils in the Cambrian was canon in historical geology textbooks (Schuchert and Dunbar, 1933). The earliest use of the adjective “explosive,” with reference to an evolutionary rate, was likely George Gaylord Simpson’s “explosive evolution” to describe a general pattern of rapid diversification early in the history of a lineage (Simpson, 1944). Mid-twentieth-century contemporaries echoed use of this phrase in characterizing a general evolutionary pattern (Henbest, 1952; Colbert, 1953).

Use of the phrase “explosive evolution” to describe rapid diversification during the early Cambrian morphed into “The Cambrian Explosion” under obscure circumstances. The earliest published occurrence known to us is a section heading in an early version of an experimental high school biology curriculum

(BSCS, 1961). Three years later, the phrase, “Cambrian evolutionary explosion,” with the middle, qualifying adjective “evolutionary,” to distinguish it from physical or chemical processes, was used in a paper describing the evolution of oxygen in Earth’s early atmosphere (Berkner and Marshall, 1964). Ultimately, the binomial form prevailed, referring to the biosphere, and the “Cambrian explosion” has propagated ever after without explicit authorship attribution.

Eminent Precambrian geologist and paleobiologist Preston Cloud was an early critic of the adjective “explosive” to describe the Cambrian biodiversification. Cloud noted that the time scale involved could have been millions of years, hardly “explosive” in the widely understood use of the word (a point reiterated by Marshall, 2006). Cloud also remarked, presumably facetiously, that such episodes probably were not accompanied by a loud noise (Cloud, 1948).

The images conjured by “Cambrian explosion” are vivid and Internet-ready; a Google search on “Cambrian explosion memes” returned more than 300K results. However, the concept implied by the word “explosion” does not do justice to advances in our understanding since the Modern Synthesis (Huxley’s 1942 coinage describing the merger of natural selection with Mendelian genetics) was modern. A few examples: molecular phylogenetics (Suárez-Díaz and Anya-Muñoz, 2008) makes possible construction of hypotheses for evolutionary development during the “prelude” to the Cambrian (Valentine, 2002); the ability to resolve biosignatures and Proterozoic biogeochemical cycles (Rothman et al., 2003) pushed the appearance of complex biological processes deeper into the Precambrian past; measures of morphological disparity (that is, the variety of different

metazoan body plans) show that biological innovation was not limited to the Cambrian but proceeded apace as life expanded from the marine environment into new terrestrial ecospace (Deline et al., 2018); new fossil discoveries point to evolutionary continuity of biomineralizing animals across the Ediacaran–Cambrian transition (Cai et al., 2019); integration of biostratigraphical and geochemical records indicates that biological transitions of the late Proterozoic and early Phanerozoic were a series of successive radiations that built upon each other (Wood et al., 2019). In sum, the processes and the time scale over which these processes acted were more complex than implied by a phrase that signals a single event.

But perhaps the most compelling reason to reassess the use of the word “explosion” to describe biodiversification during the Cambrian, separate from linguistic lineage and disciplinary developments, is its appropriation by followers of non-scientific explanations for life’s origin. Authors of anti-evolution tracts were among the earliest adopters of the phrase (Ridenour, 1967). Misuse of the concept of an early, explosive episode of evolution continues today (exchanged life discipleship, <http://exchangedlife.com/>); in this arena, the Cambrian explosion is commonly styled as falsifying evolutionary theory and flummoxing “evolutionists,” neither of which accusations are accurate, correct, or true.

“Diversification” and “radiation” may not have the visceral appeal of “explosion,” but both alternatives are suitable, fitting, apt, proper, and applicable (Marshall, 2006; Sperling and Stockey, 2018) without carrying the implication of catastrophic rate or otherworldly mechanism. Certainly, biodiversification at the beginning of the Cambrian was unique (Erwin et al., 1987)—all those new

body plans—but no evolutionary rules were broken, nor is there mystery or discipline-dividing controversy, as is claimed by anti-science concerns who seize on the term “explosion.”

After the Cambrian, the next major expansion in biodiversity occurred during the middle Ordovician, a chapter in the history of life referred to as the Great Ordovician Biodiversification Event or GOBE (Webby et al., 2004; Harper et al., 2015; Servais and Harper, 2018; Stigall et al., 2019). The term “event” may be as problematic as “explosion” in its implication of a short time period. We note that the word “event” in GOBE is redundant, as “biodiversification” is itself an event. (Similar pleonastic phrases encountered in other venues include “sales event” and “birth event.”) We suggest, as an alternative to “Cambrian explosion,” the *Great Cambrian Biodiversification* (GCB), a construction parallel to that for the Ordovician episode, absent the redundant and problematic “event” suffix. Because the phrase “mass extinction” is applied to multiple biodiversity crises through time, even though each event is unique in the organisms affected and the contributing causes, so might “great biodiversification” become a less volatile descriptor for intervals of notable increase in life’s diversity.

We submit that, for scientific, semantic, and societal reasons, it is time to lay the term “Cambrian explosion” to rest for any use other than historical reference.

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