PALAIOS
Emphasizing the impact of life on Earth's history

PALAIOS, 2015, v. 30, 432–434
Spotlight
DOI: http://dx.doi.org/10.2110/palo.2015.003

SPOTLIGHT

CATASTROPHISM AND NEOCATASTROPHISM VERSUS COSMIC HAZARD: AGER VERSUS ALVAREZ; CUVIER VERSUS LAPLACE

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In Ted Nield's book (2011), Derek V. Ager (1923–1993), the famous British paleontologist and stratigrapher, is presented at length by his former student as the father of neocatastrophism. The ideas of violent events and processes as geological agents were revived following a long-term predominance of the paradigm of uniformitarianism ("natural processes are steady across time and space") and the gradual theory of evolution (e.g., Palmer 2003). The neocatastrophism renaissance by the late twentieth century was paired with the successful emergence of two interconnected concepts: 1) the rare event principle and 2) the bolide impact theory of mass extinction. In fact, the birth of both these ideas took place 220 years ago.

In his thought-provoking books, Ager (1973, 1993) emphasized the concept of infrequent events in Earth history, with credit given to Peter E. Gretener (1926–2008); incidentally, this priority is totally omitted by Nield (2011). Gretener, a little-known geologist from the University of Calgary, introduced the notion of rare events in a brief article as follows (Gretener 1967, p. 2197): "The rare event is defined as an event with the low probability of a particular interplay of various factors," but in the several billion years of Earth history "the improbable becomes probable and eventually approaches certainty." Or, in the funny phrasing of Nield (2011, p. 28), "Given enough time, …one of an infinite number of typing monkeys will eventually write *Hamlet.* …" This principle was applied by Gretener (1967, 1984) to meteorite impacts (see below), but also concerns other extreme events and episodic agents ("a spasm, an episode, or a punctuation;" Gretener 1984, p. 87). He claimed, "The earth's history reveals long periods of tranquility interrupted by moments of action" (Gretener 1984, p. 86). And, therefore, Hsü (1989, p. 749) rightly considered the inverse relationship between frequency and magnitude of natural events ("big events are rare, small events are common;" Gretener 1984, p. 81) as "the philosophical basis for actualistic catastrophism."

Surprisingly, in his catastrophic uniformitarianism view, Ager (1993) remained suspicious in regard to cosmic hazard (compare Nield 2011, p. 106). He treated the celebrated impact scenario proposed for the end-Cretaceous dinosaur demise by Alvarez et al. (1980)—who Ager called "the iridium boys"—with "healthy skepticism" (Ager 1990, p. 37; 1993, p. 181–192). He explained, "As one who is addicted to 'neo-catastrophism', such apocalyptic theories are very tempting, but on the whole I prefer the evidence of home-made catastrophes" (Ager 1976, p. 153). Ager stressed the "spasmodic" nature of sedimentary processes and a key role of earthly factors in shaping the geological record, i.e., "the balance of the evidence is thought to put the blame firmly on marine transgressions and regressions, controlled by plate movements and mantle plume activity" (Ager 1976, p. 131).

In his approach, Ager was conceptually parallel to the founder of geological catastrophism in the first decades of the nineteenth century, Georges Cuvier (1769–1832). Beginning from 1796 (Rudwick 1997, p. 18), this son of the Enlightenment and French Revolution considered his geological revolutions exclusively in terms of devastating sea-level changes, which he thought entirely supported by hard physical evidence from the fossil record (Cuvier 1812). Like his great antagonist Charles Lyell, he in fact applied the Newtonian *vera causa* (real cause) principle and actualistic methodology (Rudwick 1997, p. 257–258; compare Hooykaas 1970, Laudan 1987, and Rudwick 2005). In the opinion of Ager (1993, p. 1), "he was the first man to understand the geological record as it really is," as well as representing a rather "geognostic" tradition in the Earth sciences, "rigorously observational and empirical, usually detailed and local, and primarily descriptive rather than causal in its aim" (Rudwick 1997, p. 5). Consequently, in contrast to the "mere cabinet naturalists" and "mere mineralogists" of that time, Cuvier categorically rejected any causal link between Earth history and putative astronomical factors, with comets in a main role (Cuvier 1812, p. 24–33; see Rudwick 2005, p. 587). Mystical motifs were popular in astro-theological doctrines since the time of Newton and Halley (see Schechner Genuth 1997, for a review). Such Earth theories are exemplified in the well-known scenario of Whiston (1708) in which the Noachian Deluge was caused by the Earth passing through the tail of a comet, a "ridiculous" concept that was treated sarcastically by Cuvier (1812, p. 26). Other (geo)catastrophists were less categorical in this respect (e.g., Buckland 1823, p. 47–48). In particular, Gruithuisen (1848, p. 81) directly connected the ancient floods with watery comets within Cuvier's catastrophist framework.

Cuvier dedicated his principal work to Pierre-Simon Laplace (1749–1827), one of the most influential mathematicians and astronomers in history (Fig. 1; see Rudwick 1997, p. 166–168). Paradoxically, in his landmark treatise from 1796, Laplace, the founder of the analytic theory of probability, considered in depth the possibility of a comet collision with Earth. For Laplace, on a historical timescale ("in the course of a century"), the likelihood of such a cosmic calamity was very low (Laplace 1796, p. 61), but he inferred, "Nevertheless, the small probability of this circumstance may, by accumulating during a long succession of ages, become very great". This rationale contrasted with the cometary catastrophism of the eighteenth century, but perfectly corresponds with the essence of Gretener's underlying principle, as formulated 170 years later, and eventually confirmed by Alvarez et al. (1980).

Laplace further hypothesized: "It is easy to represent the effect of such a shock upon the earth: the axis and motion of rotation would be

Published Online: June 2015
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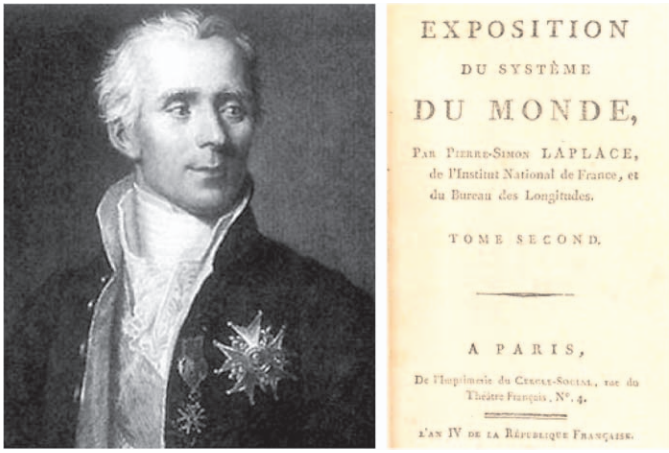

FIG. 1.—Pierre-Simon Laplace (1749–1827) and title page for volume two of his treatise from 1796 on the nebular hypothesis for the origin of the Solar System that contained innovative considerations on cosmic hazard.

changed, the waters abandoning their ancient position, would precipitate themselves towards the new equator; the greater part of men and animals drowned in a universal deluge, or destroyed by the violence of the shock given to the terrestrial globe; whole species destroyed; all the monuments of human industry reversed: such are the disasters which the shock of a comet ought to produce, if its mass was comparable to the mass of the earth" (Laplace 1796, p. 61–62). The last prerequisite is crucial, and Laplace soon modified this apocalyptic vision in subsequent editions of his cosmological theory. He abandoned the traditional concept of comets as planet-sized massive objects and was the first to propose an icy nucleus structure for these erratic cosmic bodies (Laplace 1808, p. 124–127; see Heidarzadeh 2008, p. 200–205). Having corroborated their relatively small masses, Laplace finally concluded that cometary strikes were less destructive and capable of causing only "local revolutions" (Laplace 1808, p. 213–214).

So, Cuvier's dedication to Laplace was something of an irony of fate, because he did not recognize the coherent arguments of the patron he so admired ("one of the finest geniuses of his century;" after Rudwick 1997, p. 169). Laplace's viewpoint was *per se* obviously useful in his geohistorical theory (Palmer 2003, p. 31). In effect, Cuvier's geological revolutions, against his intention, were at once spontaneously linked with an extraterrestrial cause (Olbers 1810, p. 448). Even in an extended North American edition of his discourse, the strike of a comet was considered in the perspective of vast continental inundation and a change in the Earth's axis (Mitchill *in* Cuvier 1818, p. 410–411). Intriguingly, Cuvier totally ignored Laplace's heuristic concept, although he mentioned the oldest hypothesis of meteorite bombardment by Marschall von Bieberstein and Marschall von Bieberstein (1802), "the various fragments that compose the surface of the earth falling successively from the sky like meteorites" (Cuvier 1812, p. 30). (Unsurprisingly, Cuvier knew the Bieberstein brothers well as they had studied together at the Carolinian Academy in Stuttgart.)

The immensity of geological time became progressively more evident in the early middle nineteenth century, oddly enough exemplified by Darwin's overestimate deduced from the denudation rate ("in all probability a far longer period than 300 million years has elapsed since the latter part of the Secondary [= Mesozoic] period;" Darwin 1859, p. 287). However, as a consequence of Lyell's (1830) seminal treatise (as well as the influential tract published by Arago in 1831; see Schechner Genuth 1997, p. 216–219), the evolving catastrophic anticipations of Laplace were abandoned by mainstream science and even criticized by the uniformitarians. The Earth and universe were thought in the emerging paradigm to be steady systems without violent events. For example, Guillemin (1875, p. 395) noted in the context of prior ideas on "the end of the world": "Laplace, moreover, does not seem far from believing that such a catastrophe has taken place, and the geological revolutions, the cataclysms which are the ideas of Cuvier, then dominant …, appear to him capable of being explained by such an event … Laplace, at the present day, would discard this explanation of the geological facts of past times, which modern science has since very differently interpreted."

Of course, this does not mean that in the long time span between Laplace and Alvarez, the likelihood of a collision between Earth and a large cosmic object had never been seriously considered. For example, Proctor watchfully remarked that "enormous meteorites (up to) … half a mile perhaps in diameter … at long intervals fall upon our earth's atmospheric shield" (Proctor 1878, p. 165; see similar thoughts in Meyer 1898, p. 249, and Schwarz 1909). Recent estimates of the bombardment rate for small $\sim$ 1 km projectiles are more frequent than 1 per 1 Ma, but giant cosmic objects, with diameters of $\sim$ 10 km, impact only every 100 Ma (e.g., fig. 1 in Chapman 2004). On the other hand, in developing the probabilistic Laplacian approach, Olbers (1810, p. 429) had already approximated the comet "shock" recurrence period as $\sim$ 220 Ma (compare the giant comet collision frequency of Napier 2014).

In conclusion, thanks to Laplace, extraterrestrially triggered events became an inevitable natural element of the geologic past, even if the magnitude of the resulting ecosystem perturbations remained (and still somewhat remains) disputable. Laplace may indeed be considered as the conceptual father of both the rare event and bolide impact hypotheses, formulated with a scientific rigor in the broad context of a causal link between astronomy and geology (Schechner Genuth 1997, p. 208–209). Furthermore, the rare event principle also generally refers to volcanic paroxysms as a trigger for biosphere turnovers, a concept established in the early twentieth century (Racki 2014). These French conceptual roots of mass extinction and cosmic catastrophism have largely gone unnoticed in the modern literature, with few exceptions, e.g., Sagan and Druyan (1997, p. 280) and D'Hondt (1998, p. 162). They are an exemplary case of a premature hypothesis ("ahead of its time;" Hook 2002). The aversion to awkward cosmogony in the great days of the rational catastrophic school (six French and five English editions of Cuvier's popular essay between 1812 and 1830) was so profound that Cuvier and his followers (e.g., Élie de Beaumont, Frapolli, Murchison, Deville; see Hooykaas 1970 for a review) overlooked Laplace's milestone concept (with the notable but disregarded exception of Boucheporn 1844); this lost initial opportunity indirectly resulted in blocking the dispersion of this idea for ages. Now, a compelling argument can be made to recognize the all-embracing scientific eminence of Pierre-Simon Laplace, the visionary genius whose pioneering ideas foreshadowed modern understanding of the Earth and universe. As Drake and Komar (1984, p. 411) declared, "The study of the development of ideas in our science, besides providing perspective and a sense of continuity, could also reveal concepts applicable to the modern paradigm or the creation of a new one."

ACKNOWLEDGMENTS

I am grateful to David Bond, Paul Wignall, and Vincent Courtillot for critical examination and helpful comments on a draft of this essay.

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Received 9 March 2015; accepted 13 March 2015.