Troubles in Paradise "In the Beginning" James Downard
1.2 • Getting a Grip: Dinosaurs and Mass Extinction (Updated 29 July 2017)

1.2 Section 1—The Bigger Picture of general extinction rates over Deep Time.

First off, it is essential to know that most of the extinction that has happened over the billion years or so of multicellular life have *not* been taking place as mass events, as David Raup (1933-2015) has indicated, Raup (1991, 80-85; 1994, 6760). Smaller scale extinction events can occur during an overall radiation of new forms, Quantal & Marshall (2009), while adaptive radiations can spawn cryptic "extinction" pulses when all that has happened is the diversification rate has shifted slightly, Crisp & Cook (2009). Many individual groups show localized extinction events in exactly this less dramatic way, such as the several Triassic collapses covered in Steven Stanley (2009) of ammonoids (nautilus-like cephalopods that were major marine predators during the Mesozoic) and conodonts (chordate cousins hanging on from the Cambrian that are discussed more in **Chapter 2** of Downard (2004).

Moreover, it isn't even the case that the background extinction rate has remained constant. Fastovsky & Weishampel (1996, 388-390) noted there appears to be a general decline in the rate at the family level, and if you look more specifically at cases like the invertebrate genera extinctions (**Figure 1** below) you see those are likewise substantially higher back in the Cambrian and into the early Ordovician than later on. The review by Valentine (2004, 453-458) made similar observations. These suggest larger dynamic patterns (dare I say, *evolutionary* ones) are at work, where the earliest models of a newly appeared lineage are more prone to failing the tests of life, while the forms that persist to successfully leave descendant lineages are those that have been honed into a more reliable configuration, less subject to perturbation unless something really drastic happens.

It is that deviation from the norm during mass extinctions that grab people's attention, though. The **Ordovician**, **Devonian**, **Permian**, **Triassic** & **Cretaceous** periods all ended in die-offs so intense that significant changes afterward in what was alive justified putting new labels on them (especially so for the Permian extinction, ending the Paleozoic Age and ushering in the Mesozoic, in turned capped by the Cretaceous event). But it is a sobering reminder of how vast the carpet of Deep Time has been to realize that these five big episodes of mass extinction, momentous though they certainly were for things living at the time, together involve *only 5% of all extinctions*.

In other words, 95% of life has died out the old fashioned way, *not* in mass extinction events.

Oceanic plankton are stars in this area of comparative stability: while they go extinct given enough time just like everything else that has ever lived, they tend to do so fairly gradually as climate changes filter out the less successful. For example, the radiolarians over the last 17 million years reported by Kamikuri *et al.* (2009), with an uptick in their extinction rates 15-11 Ma coinciding with dropping sea temperatures during the formation of the Antarctic ice sheet.

Rich *et al.* (1996, 103) highlight one special yardstick: "Many a paleontologist has lived a long and useful life without seeing fossil flagellates, ciliates, or even radiolarians. But no one who deals with so-called invertebrates can afford to overlook the Foraminifera, whose name is commonly shortened to 'forams.' Not only are they the most abundant and best-preserved fossil protists; they also are the most useful of index fossils. No one knows how many oil wells they have helped locate or how many formations they have helped to identify and date." Summarizing work dating back into the 1980s, E. Thomas (2003, 319-320) noted how "Rapid extinction of many deep-sea benthic foraminiferal species at the same time is very unusual in earth history, and most faunal changes of deep-sea faunas occur gradually, over hundreds of thousands to a few million years."

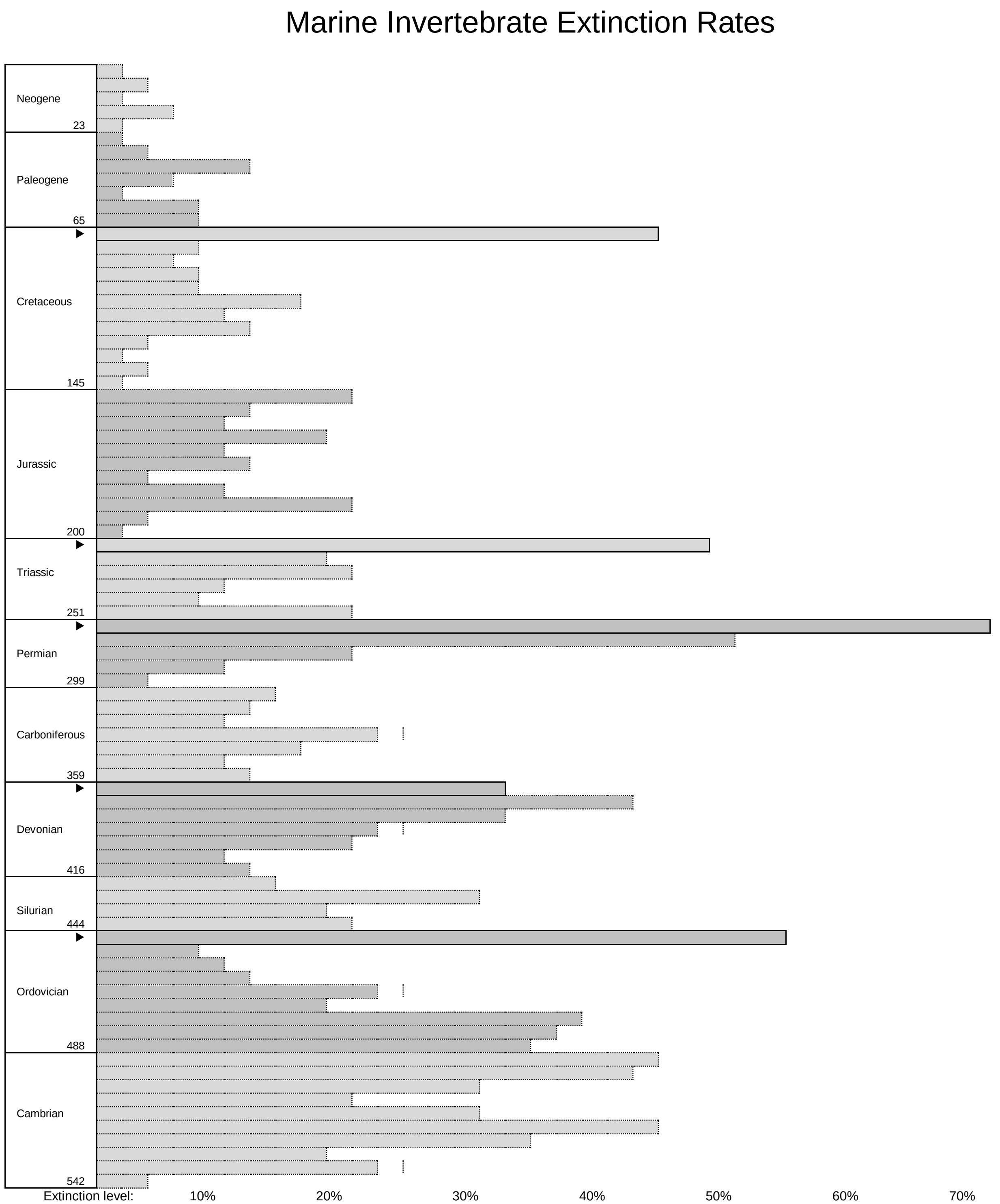

Figure 1. Adapted from *Prehistoric Life* (2009, 33). Mass extinction episodes are highlighted by an icon (▶) and darker bordered boxes, which may be compared to the more graded rate data in **Figure 2** below. The ups and downs of the cycles show interesting variety: note the overall declining rate before the abrupt Ordovician peak, contrasting with a steadily rising rate for the Devonian (cumulatively represent a lot of life checking out before the end of the period), in turn contrasting with the steeper spikes during the later three events.

The hardy foraminifera experienced a titanic decimation exactly *once* in their entire history, and it *wasn't* associated with a mass event. As a group, they had made it through several mass extinctions, including the K-T, Alegret *et al.* (2012)—though groups of them were certainly hard hit, as noted below.

(A note for sticklers: the Cretaceous-Tertiary boundary is spelled with a K from the German, though if one wants to be current per Pillans (2004a), the division is now dubbed the Cretaceous-Paleogene. That said, for this work I will be using the older more common K-T). The foraminifera's crisis took place around 56 Mya during what was first called the Early Eocene Climate Optimum (EECO), then the Middle Eocene Climatic Optimum (MECO), and finally the Paleocene-Eocene Thermal Maximum (PETM). The Eocene was already a very warm period (reaching temperatures equaling the PETM five million years later) before a long-term chill over the last 50 million years punctuated by ice ages. Surveys by Kunzig (2011) and Kump (2011) stressed its implications for present global warming due to the aberrant conditions prevailing during the PETM spike. CO_2 levels in the Earth's atmosphere reached four times present levels, the equivalent of igniting the planet's current fossil fuel reserves in one go, Kunzig (2011, 94-96), along with a surge in methane levels, Gehler *et al.* (2016).

There was increase in volcanism during the PETM, such as in the Caribbean basin during this period, Bralower *et al.* (1997), steadily baking rocks and releasing CO_2 and methane, as well as methane hydrate outgassing from oceanic deposits (methane being an even stronger greenhouse gas than carbon dioxide, incidentally, though with lesser total impact because of its lower atmospheric concentration), D. J. Thomas *et al.* (2002), Dickens *et al.* (2003), Zachos *et al.* (2005), and P. Pearson (2010) on Bijl *et al.* (2010), Kerr (2011b) and Frieling *et al.* (2016), as well as injections of carbon from melting permafrost, DeConto *et al.* (2012). More recently, an impact event has been identified as occurring at that time, possibly acting as a triggering factor, Voosen (2016) re Schaller *et al.* (2016). Though some calcified ostracods (tiny marine arthropods) were temporarily disrupted during the PETM, Steineck & Thomas (1996), the foraminifera were especially devastated as the methane belch undercut the carbonates needed to build their shells, E. Thomas (2003).

Foraminifera tend to stratify by depth, illustrated by Fortey (2009, 61), a clue to how a dominant form could crash if the temperature, chemistry or nutrient balance alters beyond their tolerance range. Maslin & Thomas (2003) survey some of the dynamics of methane hydrates in sequestering and releasing carbon, while part of the reason for the general foraminifera success story is their diversified ability to respire nitrates along with oxygen, Piña-Ochoa *et al.* (2010).

Far removed from their benthic habitat, humans have nonetheless relied on forams for some time: Fortey (2009, 68, 228) and Stow (2010, 191-192) noted Egypt's pyramids are built of limestone packed with one species, the 40-50 Mya coin-shaped *Nummulites gizehensis*, while Hofstadter (2009, 72) connected the abrasive properties of their tiny "test" shells to lens grinding for Galileo's early telescopes.

Parenthetically, the PETM would get a big knock later in the Eocene from a most peculiar cause: the aquatic Azolla fern that proliferated in the Arctic Ocean, which because of plate movements had a poor circulation system and so when the carbon-rich ferns died they sank into the anoxic bottom, disrupting the carbon cycling system and dragging the climate downward as CO_2 levels plunged, Brinkhuis *et al.* (2006). The opening of the Tasmanian Gateway at this time contributed to the cooling trend, Bijl *et al.* (2013), as did the collision of India with Asia, where the rise of the Himalayas chilled the Tibetan plateau along with spawning a new monsoon system that shifted moisture circulation globally, Zhisheng *et al.* (2001), Gupta & Thomas (2003), Gupta *et al.* (2004), and Irving (2008) re Kent & Muttoni (2008). Tudge & Young (2009, 40-42, 52-56) offer a tidy overview of this in their argument on Eocene primate evolution, and Hodges (2006) illustrates the causal dynamics of orogeny on climate. Adding to the mix (and perhaps not coincidentally) there was also a *geomagnetic reversal* during the PETM, Y. Lee & Kodama (2009).

1.2 Section 2—Intelligent Design advocate Phillip Johnson wades into the extinction issue.

All this begs the question: while most organisms aren't going extinct in mass events, they still are going extinct, eventually—why? The simplest answer is that living things go extinct because they finally confront an environment they can't cope with. This happens to individuals all the time, of course. An antelope checks out because the lion caught up with it. But extinction in the sense we're talking about here is all the members of the group failing to make the cut. That involves the interplay of the entire species in its total environment. For all of a group to go extinct things have to happen that causes the whole shebang to dip below the minimum threshold of survival (not enough of a population to actively sustain itself in the long term).

In the case of animals, they go extinct because conditions have changed but they haven't. And the reason why that can happen at all is that organisms aren't *designed*. They can't be recalled by the manufacturer (like Toyota had to in 2010 over dangerously malfunctioning accelerator pedals) for a politic retrofit to keep them adapted to their altered environment. They can only run with the set of systems they were born with. If they or their ancestors didn't have the luck of getting mutations that opened up new potential opportunities for them, that's it—checkout time.

Hence the very existence of extinction as a phenomenon of the living world is a testament to the impact that chance processes have on how living systems can (or cannot) adapt to an environment where continents shift around, mountain ranges rise or fall, oceans appear or dry up, forests spread or recede, and every other animal (from predators to potential competitors for your own particular niche) is facing exactly the same dice rolling game. Can your species keep on going for the next round, based on what you have in your adaptive kit bag?

Knowing the finer points of what "extinction" means in real terms spread over **Deep Time** makes it all the more informative to see how the philosophical godfather of the Intelligent Design movement, Berkeley lawyer Phillip Johnson, has approached the subject.

As it happens, Phillip Johnson reviewed David Raup's 1991 book *Extinction: Bad Genes or Bad Luck?* in the February 1992 issue of *The Atlantic*, conveniently reprised in Johnson (1998a, 41-47). Which means he had to have known about that background extinction rate and how most of that didn't involve mass extinctions. And yet he has repeatedly invoked Raup's work on mass extinctions as supposedly casting doubt on the prevalence of regular Darwinian processes rolling on during the remaining hundreds of millions of years when mass extinctions weren't happening.

From the start Johnson (1991, 57) contended in *Darwin on Trial* that, "A record of extinction dominated by global catastrophes, in which the difference between survival and extinction may have been arbitrary, is as disappointing to Darwinist expectations as a record of sudden appearance followed by stasis" (we'll get to the "stasis" issue in the next section **1.3** when we hit the Punctuated Equilibrium issue). In P. Johnson & Provine (1994), a debate at Stanford University with William Provine, Johnson reiterated this position (citing only Raup as his source) and by *Reason in the Balance* Johnson (1995a, 83) had tightened this conflation of background extinction and mass extinction into: "many authorities now attribute extinctions primarily to freakish catastrophes." There were no references to any of these "many authorities" in the slim Johnson (1995a, 226-228) research notes, not even to his sock puppet Raup.

When Johnson appeared as a very congenial guest on Hank Hanegraaff's *Bible Answer Man* radio show in December 2000 he had kneaded his misunderstanding into the blanket conviction that "the dinosaurs, and indeed perhaps all extinctions, were brought about by catastrophic event."

Johnson's behavior here is an important clue about what we will be discovering in terms of the tortucan mind. Even though the existence of a pervasive background extinction rate was clearly in evidence in the Raup work he had explicitly reviewed, he never saw that aspect of it, only the mass extinction spikes that seemed congenial to some allegedly non-Darwinian process whereby animals might be extinguished for other than their (designed?) adaptive perfection.

Interestingly, Johnson (1998a, 41) stressed that his review of Raup's book back in 1992 had provoked letters to the editor that "were vehemently hostile, but Raup himself wrote to me privately and said I was right on target." Raup has indeed been impressed with Johnson, as Witham (2002b, 69, 97-102) noted, and does believe that "impact-caused extinctions may actually dominate the extinction record" (personal communication, 2003). Insofar as Darwin abhorred the idea of mass extinction, in that sense Raup's evolutionary views may be considered "anti-Darwinian."

But it is instructive to take a look at those "vehemently hostile" letters to measure some of Johnson's own gloss. There were six, of which only two emanated from scientists. None took aim at Raup's position, but were all very doubtful about how *Johnson* framed the issue. Even the three pithiest remarks were fairly tame, though—suggesting Johnson wears rather a thin skin.

To wit: Robert Michael Pyle of Gray's River, WA suggested in the May 1992 issue that Johnson was "a law professor slumming among scientists." In June, McGill University genetics professor G. A. C. Bell likened Johnson to that "tawdry band" of literary outsiders who periodically announce the Death of Darwinism (such as George Bernard Shaw or Arthur Koestler)—cf. Peter Bowler (2002, 228) here.

When L. J. Marsh of Minneapolis described him in September as "pugnacious," Johnson rejoined:

> Rare catastrophes can be fit into a Darwinian framework if we assume that natural selection was at other times killing off the less fit and preserving the most fit. Suppose, however, that extinctions nearly always occurred in catastrophes, and that the victims were as proficient as the survivors at flying, seeing, reproducing, or whatever. That is what David Raup is suggesting. But if ancient species that were relatively unproficient at flying or seeing did not as a consequence dwindle and eventually die out, then what sense does it make to say that 'natural selection' produced improved capabilities in their successors?

A lot of abstract supposing here, all wonderfully divorced from specific example, which as we'll see is the hallmark of Johnson's apologetic Wedge approach to combating evolutionary naturalism.

Yet no matter how the fossil pie is sliced, Johnson's recurrent supposition that "extinctions nearly always occurred in catastrophes" is tenable only if he restricts his attention to *mass* extinction events, and he can sustain his broader supposition that normal adaptive evolution hadn't been going on the remaining 95% of the time only by paying no attention to any of the actual data. Worse, we (and Johnson) know of at least one very famous animal "relatively unproficient at flying" that apparently went extinct independent of any catastrophe: *Archaeopteryx* detailed in **Chapter 4** of Downard (2003b) and **Chapter 2** in Downard (2004). Unless of course Johnson has some Jurassic cataclysm hiding up his sleeve that he has yet to spring on the scientific literature.

Such rarified disdain for the body of available information makes Johnson's concluding *Atlantic* reply sentence (p. 13) to Mr. Marsh of Indianapolis especially pompous: "Pressing awkward questions like this is not being 'pugnacious'; it is being scientific."

Well, let's try being "scientific" shall we?

When you look at what was happening at the time of those decidedly rare mass extinctions it is clear something unusual (and therefore genuinely interesting) was going on, with the Permian crash being the most severe, and the earlier Ordovician event coming in second. Just how severe an extinct event is depends on what measure you're using: an enormous number of species or genera can go extinct without necessarily removing all members of their family or class, as illustrated in **Figure 2** below. Şengör *et al.* (2008) and S. Wang & Bush (2008) provide some guidelines for assessing how severe a mass extinction is, and Mander *et al.* (2010) illustrate the challenges in identifying the level of disruption of plant diversity in the Triassic extinction. Hull (2015) focused on the Permian and Cretaceous events, in the larger context of how much those big events drive larger macroevolutionary or ecological turnovers (it's a mixed bag).

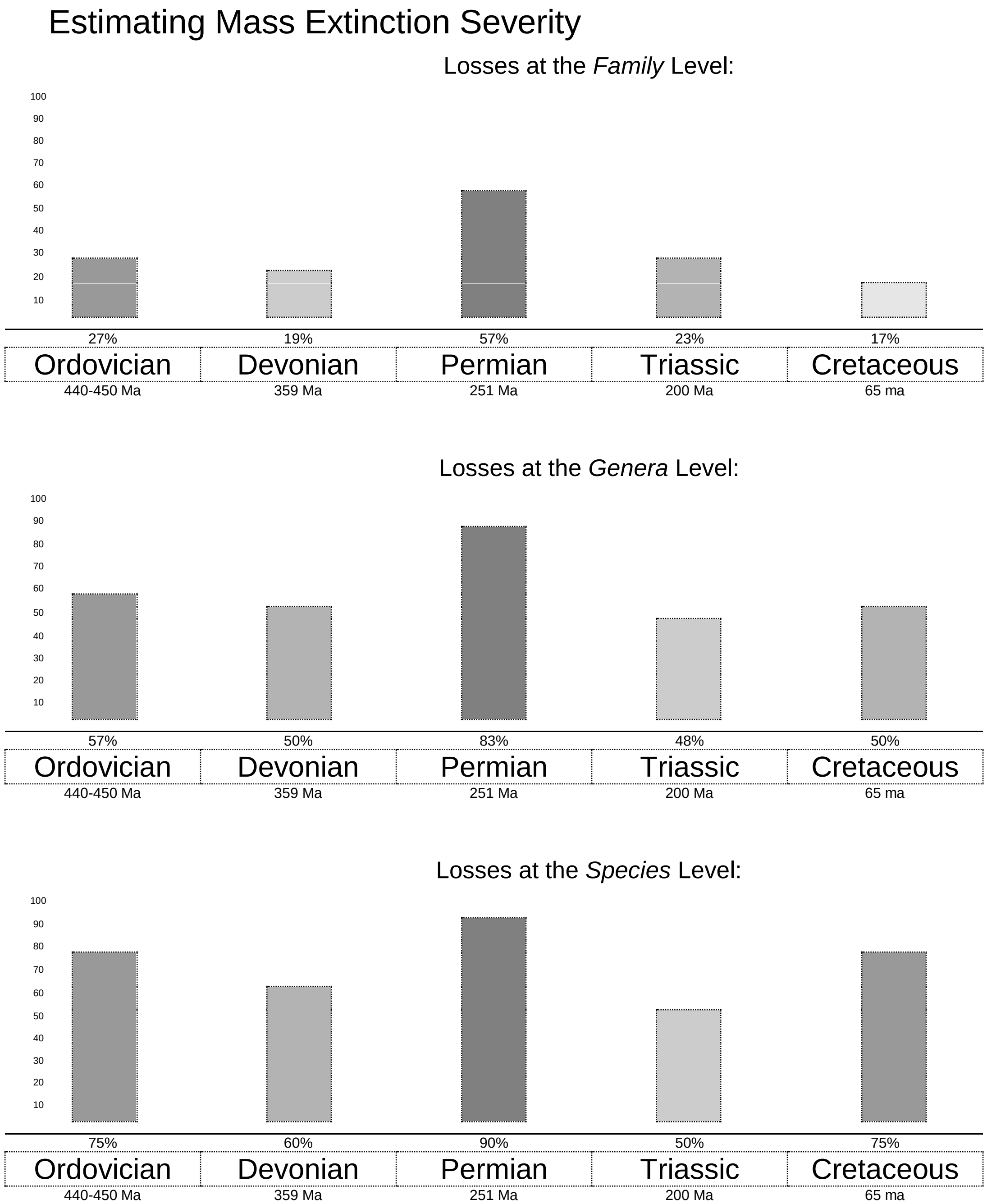

Figure 2. Various estimates have been made for the severity of mass extinctions. The percentages here reflect the "Extinction Event" entry at *wikipedia.org* (accessed 5/3/2010) that drew primarily on a compilation by Baez (2006). There may have been two main pulses in the Ordovician extinction, indicated in the broader date ranges.

Measuring the severity of mass extinctions depends on which analytical tools are used and how broad the dataset, as Stanley (2016) reminded. But by all accounts the Permian event was the worst, decimating almost *90%* of genera living then. For "well-skeletonized" marine families (thus better represented in the fossil record than soft bodied ones) illustrated in May (2012) the Permian stands out as a gigantic plunge in diversity that all but wiped out the previous 200 million years of general stability, followed by a resumed fairly steady climb afterward to much higher levels known today. Because most living things dwell in the sea, the odds were that marine life would tend to suffer more than their terrestrial cousins, though even at that around 70% of land species died out in the Permian event, hitting even the otherwise imperturbable insects, where eight entire orders went extinct, Stow (2010, 74).

The earlier Ordovician event tracks in second at around 60% of all genera checking out—sparing land life only because back then plants and animals hadn't actually got out of the seas. See Finney *et al.* (1999) and Finnegan *et al.* (2012) on the Ordovician; A. Murphy *et al.* (2000) on the Devonian with Casier *et al.* (2002) illustrating how ostracod losses confirmed its global extent; and Erwin (1996), Hoffmann (2000), Jin *et al.* (2000), M. Benton (2003) and Z. Chen & Benton (2012) on the Permian event. How the big five extinctions fit in on the larger picture of earth history may be seen in **Figure 1** in Downard (2003b, 15), and Eldredge (2014) offers an illustrated take on the issue for a general audience.

It is not unreasonable to expect something rare and distinctive lay at the root of these evident breaks in continuity, and several analyses have detected periodicities in extinctions: a 26 million year cycle identified by David Raup & John Sepkoski (1984) and favored by Davis & Muller *et al.* (1984)—later replaced by a much longer 62 million year pulse, Kirchner & Weil (2005) re Rohde & Muller (2005). Such leisurely cyclical elements have understandably prompted some to look skyward for their prime suspects. Least likely in this department is the "Nemesis star" theory promoted by Sepkoski and Raup, that the sun has a dark stellar companion that periodically orbits dangerously close. The chief problem with the Nemesis Star scenario is that advocates tried to force the known extinction data into a shoehorn of periodicity (or *periodicities*, since the initially proposed 26 my cycle would seem to suggest a longer 52 my rate, rather than the 62 my one Muller subsequently culled from Sepkoski's data) dictated by what was itself a purely hypothetical astronomical cause, Pellegrino (1985), R. Ehrlich (2001, 102-121), M. Benton (2003, 138-140) and Prothero (2007, 18).

Astronomical factors can affect life on earth, even at the scale of the solar system's leisurely transit in and out of dust-laden spiral arms, A. Parker (2003, 293-295). More locally, geologist James Croll (1821-1890) studied the climate impact of variations in Earth's orbital eccentricity in the mid-19th century, refined in the 1940s into the ice age cycling models of mathematician Milutin Milanković (1879-1978), with the quirks gradually worked out as to how much those cycles modulated the climate, Hayes et al. (1976), Imbrie (1982), Elkibbi & Rial (2001), Rial (2004), Tziperman *et al.* (2006), Nield (2007, 109-112) and Hilgen (2010), with recent tweaking noted by Kerr (2013c). The Milankovich cycles not only constrain recent glaciation, Huybers (2011), but appear to modulate global warming periods too, Lourens *et al.* (2005). Oxygen and carbon isotopes vary in this way, Stow (2010, 18), and differing sunlight intensity by latitude alters oceanic temperatures in complex ways, Philander (2010) re T. Herbert *et al.* (2010) and Martin-Garcia *et al.* (2010). This climatological dance has been going on for a long time, as evidenced by Jurassic sediments, Sha *et al.* (2015), and others dating back 1.4 billion years, S. Zhang *et al.* (2015).

While Nemesis is problematic, the asteroid or comet impacts that inspire turgid movie plots (*Armageddon* pops into mind) are far less so. A devastating impact certainly occurred at Chicxulub in the Yucatan peninsula close to the time of the K-T event, Carlisle (1995) and Smit (2008), which contributed a nice oil reserve to boot, Nishimura *et al.* (2000). Dingus & Rowe (1998, 11-104), Courtillot (1999, 119-134), Lubick (2001) and Palmer (2009, 182-187) place the evidence in larger context. Belcher *et al.* (2003; 2009; 2015) have worked out the parameters of the K-T fireball and subsequent fires, and the analysis of ejecta deposits by P. Schulte *et al.* (2010) and the accompanying "impact winter" detected by Vellekoop *et al.* (2014) support its role as an extinction trigger. Keller & Stinnesbeck *et al.* (2004) also suggested Chicxulub predated the K-T by some 300,000 years, but Pälike (2013) re Renne *et al.* (2013) confirmed a K-T correlation.

As for other mass extinctions, the giant Mancouagan crater in Canada dates to the Late Triassic, though its extinction effect may have been only localized, Walkden *et al.* (2002) and Onoue *et al.* (2012). A side issue concerns how much (or whether) the impact may have contributed to the rise of the dinosaurs, thus opening up *adaptive opportunities* for the survivors in exactly the way the likes of Phillip Johnson are loathe to imagine: Kerr (2002a) and Thulborn (2003) re Olsen *et al.* (2002; 2003), Kerr (2003b) on Basu *et al.* (2003), and more broadly by Fraser (2006, 243-256). More recently another impact contender has appeared: the smaller Rochechouart crater in France, which new dating also puts at the Triassic extinction boundary, Schmieder *et al.* (2010) with perspective by R. Smith (2011).

A Devonian impact (or even impacts) has also been proposed, though not without criticism, Racki (1996), Sandberg *et al.* (2002), Ellwood *et al.* (2003; 2004) *contra* Racki & Koeberl (2004). A modest impact in the Baltic around 455 Mya appears unconnected with the Ordovician extinction, Suuroja & Põldvere (2004), nor does a possible larger asteroid breakup around 468 Mya relate to earlier Ordovician biodiversification, Lindskog *et al.* (2017). Perhaps most significantly there doesn't appear to be a solid impact correlation for the most intense event in the Permian, covered by Kerr (2005a) and Marshall (2005) re P. Ward & Botha *et al.* (2005) and P. Ward *et al.* (2005), with the evidence considered still slim by the time French & Koeberl (2010) and Racki *et al.* (2011) assessed the forensic clues (and their limitations) whereby ancient impact events are identified (from shocked quartz and microtektites to larger crater features heavily eroded in **Deep Time**).

The snag regarding the role of impact events is well illustrated by the K-T itself, where support for the impact hypothesis grew rapidly in paleontology but was still not universal, Sabath (1996). Outright bolide skepticism such as Dorrik Stow (2010, 176-186) is even rarer these days, with general acceptance of the Chicxulub event of the Switek (2013b, 190-211) form common, but assessing the blast effect forensics (searing heat and vegetation fires, followed by global winter under a prolonged dust-shrouded darkness) trip on the peculiar range of victims and survivors.

Though even the smallest chicken-sized dinosaurs perished, the cold-blooded egg-laying frogs and most crocodiles made it past the Cretaceous, along with pollen-eating moths and light sensitive corals, Fortey (2009, 190-193). Stow (2010, 163-166) likewise noted a complex mix: the planktonic coccoliths (occupying the base of the Cretaceous marine food chain) were decimated, as were 75% of marsupials and birds and 25% of crocodiles, turtles and fish, but the majority of placental mammals survived, as well as lizards and snakes—though more recent work does suggest lizards and snakes suffered an 83% species-level hit after all, Longrich *et al.* (2012b). Other groups show similar variation: Late Cretaceous mollusc taxa underwent both gradual and abrupt extinction episodes, C. Marshall & Ward (1996), and while some foraminifera seemed to have emerged without much disruption, Alegret *et al.* (2003) and Alegret & Thomas (2004), the dramatic disruption of the ocean habitat led to 90% of calcifying nannoplankton and foraminifera going extinct, along with all the long-successful ammonites, Keller *et al.* (2009), Gallala *et al.* (2009) and Tyrrell *et al.* (2015).

Geerat Vermeij (2010, 64-65) spotted some patterns to the survivors, and not just in the K-T event. Animals that made it through easiest were ones that could hunker down in a crisis, going inert and able to tolerate some starvation until things settled down (crocodiles and turtles, for example), or at least isolate themselves from a stressful environment (clams can shut their shells tightly in a way the more vulnerable brachiopods can't). Neil Shubin (2013, 137) noted the most common feature of the animals that survive a mass extinction (besides dumb luck) is their *distribution range*: taxa spread over wider areas stand a better chance of persisting after the crash than niche inhabitants—though again, as with **Figure 2** above, it appears to matter at what taxonomical level the animals are viewed at (genera versus species for instance), as explored by Jablonski (2005).

Given these details it is improbable that any single event (intense though they may have been) "causes" a mass extinction. It is more likely multiple factors play a role, where an impact comes along just as the last straw to tip an otherwise unstable arrangement over the edge, as in the "press-pulse" model of mass extinction proposed by Arens & West (2008). It is relevant that the marine side of the Ordovician, Permian and Cretaceous extinctions took place against a background of overall *increasing* origination of new species, Bambach et al. (2004, 533-535), suggesting something out of the ordinary was stressing the system.

Recent work suggests the Ordovician marine ecology was undergoing climate stress before the main extinction drop, Holland (2016) re Sheets *et al.* (2016). And a comparable wind-up appears to have taken place preceding the Cretaceous event, in both marine and terrestrial realms, Stow (2010, 172-176) J. Mitchell *et al.* (2012) and Sakamoto *et al.* (2016). A further clue that something unusual was going on is how late Cretaceous temperatures well before any impact were yo-yoing up and down over geologically brief cycles of tens of thousands of years by as much as 20° C, Qiu (2015b).

A predator-prey mix in North America dominated by tyrannosaurs hunting ceratopsids, for example, would represent an overspecialized ecosystem primed for a fall. All it needed was a serious nudge or two.

Which brings us to another potentially serious culprit: magmatic plume breaches. Spun off by plate subduction, these form volcanic chains like the Cascades in my Pacific Northwest backyard, or as fixed "hot spots" can generate volcanoes along a conveyor belt like the Hawaiian Islands or the many extinct volcanic calderas leading up to the really massive and still dangerously active one in Yellowstone Park.

The dynamics of the Hawaiian hotspot turn out to be especially complex, as eruptive episodes fluctuate along a shifting oceanic plate sliding over it, Tarduno (2008), Tarduno *et al.* (2009), Kerr (2009g) re Wolfe *et al.* (2009), and Clague & Sherrod (2014). See Courtillot (1999) on volcanism generally, Condie (2001) and Jackson & Carlson (2011) on mantel plumes, and Bindeman (2006) on supervolcanoes. Work has continued regarding the Yellowstone caldera to better understand its geological dynamics, Achenbach (2009) and Shapiro & Koulakov (2015) re H. Huang *et al.* (2015), since any resumption of its activity could be quite catastrophic. Such activity has been going on a *very* long time, of course, at least as far back as the Yellowstone-style eruptions in the Blake River Group in Canada 2.7 Ga, Pearson & Daigneault (2009), or the Warakurna large igneous province in Australia 1.0 Ga, Wingate *et al.* (2004), though back then only microbial sea life would have been the targets of any changes in oceanic conditions.

It looks far from coincidental, though, that there was massive volcanism during *four* of the five mass extinctions periods, sometimes trailing on for millions of years and significantly stressing the ecosystem. Oceanic volcanism (as a tectonic island arc collision eventually formed the Ural Mountains) disrupted the late Devonian, D. Chen *et al.* (2005), Brown *et al.* (2006) and Pravikova *et al.* (2008). The **Siberian Traps** hit the late Permian like a hammer, Browne (1998a-b), Wignall *et al.* (2009), Ogden & Sleep (2012), and twenty years of geophysical research has led to its acceptance as the main trigger for that extinction event, Kerr (2013e). The Triassic had the **Central Atlantic Magmatic Province** (CAMP)—recalling though that the "central Atlantic" was then nestled well inland and just opening up as the Pangea supercontinent began to fragment, eventually ending up as a long strip along the east coast of the United States, a sliver of the Iberian Peninsula in Europe, a big chunk of Brazil, and most of western Africa, illustrated in Witze (2017a, 296). Continuing research on the CAMP include Olsen (1999) re Marzoli *et al.* (1999), Rampino (2010) re Whiteside *et al.* (2010), Schoene *et al.* (2010), Schaller et al. (2011a-b) with caveats by Rampino & Caldeira (2011), Kerr (2012m), S. Perkins (2013) re Blackburn *et al.* (2013), and Percival *et al.* (2017).

Finally, India's **Deccan Traps** destabilized the environment as the subcontinent drifted north from its former location parked down by Antarctica, to cross the Réunion Island hotspot late in the Cretaceous before eventually slamming into Asia in the Eocene to push up the Himalayas, Kerr (2003d) re Ravizza & Peucker-Ehrenbrink (2003), Irving (2008) re Kent & Muttoni (2008), Keller *et al.* (2009), Kerr (2012i), Richard Stone (2014c) re Schoene *et al*. (2015), and Glišović & Forte (2017). To close one circle, though, the Chicxulub impact may have triggered a final paroxysm in the Deccan province lasting a further half a million years on into the Paleogene, curbing the biotic recovery—a resonant focusing of energy due to its coincidentally antipodal position in the Indian Ocean, Sanders (2015) re Mark Richards *et al.* (2015), and Renne *et al.* (2015).

The threshold for magma plume danger appears to be how much oceanic crust they recycle, Wignall (2011) re Sobolev *et al.* (2011). Knowing what modest plumes do beneath Hawaii, Yellowstone and the Cascades, consider the impact of far larger reserves nearer the surface. Besides basalt carpeting hundreds of thousands of square miles, such as Siberia's Putorana Plateau illustrated by map in van de Schootbrugge (2005,37) and photographically by Palmer (2009, 108-109), their gas emissions (notably carbon dioxide and sulfur, but also chlorine and fluorine) don't bother just terrestrial life—they hit the marine ecosystem that helps calibrate Earth's climate. The complex feedback dynamics are explored in more detail by Schobben *et al.* (2015).

Magma plume-driven extinctions play out over much longer time frames than splat asteroid impacts, though the biotic extinction event itself may still play out during a narrower window within an overall stressed ecosystem, as appears to have been the case for the Permian event constrained within a geologically very brief 60,000-year window, Erwin (2014) re Burgess *et al.* (2014). The Siberian Traps continued to spew carbon dioxide, affecting the climate for 5 million years after the extinction and possibly raising tropical ocean temperatures in the Early Triassic to an astonishing 40°C (104°F), Bottjer (2012) re Y. Sun *et al.* (2012)—though disputed by Goudemand *et al.* (2013), prompting a tart rejoinder by Sun *et al.* (2013).

Conditions grew so inhospitable for vertebrate sea life that they had to retreat toward the cooler poles, opening up a niche allowing heat tolerant stromatolite formations (layer cakes of bacteria normally devoured by grazing animals of many types) to make a brief comeback—a situation that appears to have occurred also after the earlier Ordovician extinction, Sheehan & Harris (2004). Over several hundred thousand years the CAMP eruptions ran the roller coaster again in the Late Triassic, with sulfurous clouds cooling the climate competing with CO_2 warming it, fueling fire surges that significantly affected plant distribution, van de Schootbrugge (2010) re Belcher & Mander *et al*. (2010).

Or take Gastaldo *et al.* (2009) with perspective by Berardelli (2009), reevaluating the major Karoo Basin fossil beds in South Africa suggesting the Permian climate and faunal impact lasted over a hundred thousand years. Incautiously, both *Answers in Genesis* (2009b) and Brian Thomas (2009d) at the *Institute for Creation Research* pounced on this work to argue that the longer timeframe actually meant the complete opposite. As Thomas put it: "perhaps the layers that Gastaldo traced were formed from tidal oscillations that occurred while the earth was still underwater during the year-long Flood."

Thomas didn't stop to explain how such an event could have preserved the tiny crustacean burrows and fossil footprints the paleontologists found there. The burrows in particular could hardly have been formed along with the rock they are dug in, nor could they be filled in later unless there had been a "later" for that to happen, when the tiny tenant had moved on, Gastaldo & Rolerson (2008). The glib ease with which Young Earth Creationist authors invoke the Flood as a catchall explanation for deposits without examining the finer details are on display in **Chapter 3** of Downard (2004).

Sea level fluctuations have also been correlated to marine extinctions, Peters (2008), with Stow (2010,75) noting the formation of the Pangea supercontinent dropped sea levels by 250 meters during the Permian, leading to substantial habitat loss as only 13% of continental shelves remained submerged. The Permian ocean underwent a complex shift as a burst of oceanic anoxia churned large amounts of carbon dioxide into the upper oceans, in turn affecting ocean acidification, Knoll *et al.* (1996), Jonathan Payne *et al.* (2010) and Brennecka et al. (2011), spurred on by the Siberian Traps volcanic activity, Hand (2015c) re Carlson *et al.* (2015). Zhang *et al.* (2017) identified severe fluctuations between sulfidic and oxic conditions during the Permian/Triassic extinction turnover.

Prothero (2016, 45-59) included sea level dropping as a major factor in the Cretaceous event (along with the asteroid splat and the Deccan volcanic activity), and it's known oceanic anoxia occurred then too, though with considerable controversy about the forensics, Gibbs *et al.* (2011) *contra* Erba *et al.* (2010; 2011), and Higgins *et al.* (2012).

The release of methane hydrates trapped in ocean sediments may have been another factor, Berner (2002), M. Benton (2008b) and S. Shen & Crowley *et al.* (2011). Methane hydrates have been proposed for the mysterious Toarcian Oceanic Anoxic Event (TOAE) taking place early in the Jurassic (182 Mya), Hesselbo *et al.* (2000). Study of the phenomenon has been hampered by the facts of ocean sediment preservation: much early seafloor has simply disappeared due to plate movements in the scores of millions of years since. Tectonic activity overall appears to have been a contributing factor along with carbon cycling oscillations modulated by the broader astronomical Milankovich patterns that affect climate generally, Gröcke *et al.* (2011), Izumi *et al.* (2012), and Huang & Hesselbo (2014). Scientists take note of odd events like the TOAE because the concurrent extinction involving marine life may offer clues for assessing the impact of comparable ocean anoxia in modern ecosystems, van de Schootbrugge *et al.* (2005), Caswell *et al.* (2009), and Ullman *et al.* (2014).

Rothman *et al.* (2014) identified an even more intriguing line of tumbling Permian dominos: the Siberian volcanism increased nickel concentrations to the point where a group of new bacteria (*Methanosarcina*) that required that metal for their acetoclastic pathway to convert marine organic carbon to methane went on an ecologically disastrous methanogenic binge. This scenario has received further support on the Permian nickel production side by Le Vaillant *et al.* (2017).

Methane emissions appear to have played a similar role in the Triassic, Ruhl *et al.* (2011), as the overall changes in ocean chemistry reverberating after the Permian event prompted a major shift in photosynthetic phytoplankton from the green superfamily in favor of their biologically distinct red superfamily cousins, Quigg *et al.* (2003)—yet more instances of adaptive evolutionary changes invisible to antievolutionists ill-suited to climbing down from their doctrinal pedestal to take a closer look.

Peter Ward (2006) noted the further role of dissolved hydrogen sulfide during the Permian, Triassic and Cretaceous events, connected to oxygen depletion in the atmosphere. In that respect the Permian case was the most extreme, with oxygen levels plunging from 30% to only 12% in the early Triassic, Sheldon & Retallack (2002), M. Benton (2003), and Kerr (2005b) re Huey *et al*. (2005). To put this in perspective, Ward (2005b) calculated that any modern mountaineer time-traveling back to the Triassic (and used to our 21% oxygen level) would have been gasping for air at only 4.5 km altitude (around 14,000 feet). Later in the Cretaceous oxygen levels rebounded, Gale *et al.* (2001), putting a crimp on the C_3 angiosperm plants just appearing then, while allowing the companion C_4 plant groups to get a stem up, so to speak—still more adaptive evolution for antievolutionists not to observe.

Such broad fluctuations in atmospheric oxygen levels would have had a profound impact on flammability, Belcher & Yearsley *et al.* (2010). Below 16% fires are suppressed completely, remain still low until 18.5%, and substantially increased for 19-22%. High-risk periods were during the Carboniferous (350-300 Ma) and Cretaceous (145-64 Ma), intermediate levels during the Permian (299-251 Ma), Late Triassic (285-201 Ma) and Jurassic (201-145 Ma), and lowest Early-Middle Triassic (250-240 Ma). It is of interest that a depletion of oceanic oxygen levels occurred prior to the Devonian extinction (perhaps caused by nutrient-rich runoff from the proliferating land plants disrupting reef communities, more spin-offs from evolutionary adaptation), along with some massive mountain building in the Euramerica continent that formed during the Devonian: the Caledonide and Appalachian ranges, *Prehistoric Life* (2009, 110-111). Though highly eroded today, the Appalachians would rise to Himalaya heights, with presumably comparable impact on atmospheric circulation patterns.

Even larger climate cycles appear to be playing a role in mass extinctions too, as the seesaw from one mode to another (warm greenhouse to cold icehouse and back again) sets up the ecosystem for a fall. As illustrated in Fortey (2009, 42) four of the five mass extinctions took place at the beginning and ends of either an icehouse (Devonian and Permian) or greenhouse phase (Triassic and Cretaceous), and the fifth (the earlier Ordovician one) occurred during a sharp temperature drop and glaciation phase during what was otherwise a greenhouse period. Continental arc volcanism appears to be a major driver of these icehouse-greenhouse cycles, Kump (2016) re N. McKenzie *et al.* (2016).

That "odd man out" Ordovician 450 Ma may reflect another player. Although there were massive pyroclastic events in the Ordovician, they don't appear to have triggered the later extinction, Huff *et al.* (1992) and Botting (2002), but perhaps scientists have missed links that played out over a longer timeframe (remembering also that the farther back you go in time, the less available geological deposits there are to piece together the dynamic puzzle). With animals living in *shallower depths* being hit the hardest, though, Melott *et al.* (2004) suggested a rare but catastrophically dangerous *gamma ray burst* from some nearby star as the culprit, blasting away the protective ozone and explaining both the preferential extinction and concurrent climate change—though see Heim (2008) on the nuances of Ordovician extinction rates, and Vandenbroecke *et al.* (2010) and Finnegan *et al.* (2011) clarifying the feedback role and extent of the glaciation occurring then. Another wrinkle that's turned up: a significant depletion of *selenium* in the oceans also appears to characterize the Ordovician, Devonian and Triassic mass extinctions, Long et al. (2016), with as yet uncertain implications for the dynamics of ocean chemistry.

If you get the impression that trying to isolate all the many factors that can contribute to shifts in climate and trigger extinction events (mass or otherwise) is no easy trick, you've got it right. Genuine scientific reasoning involves exactly that level of caution, dealing with all the varied factors that might come into play. This may be seen from general presentations such as van de Schootbrugge (2005) at the college level to technical papers like Zachos *et al.* (2001), E. Thomas *et al.* (2006) and E. Thomas (2007) on the interlocking causes of the Cenozoic PETM, or Steven Stanley (2010) on the affect bacterial metabolism can have on carbon being released or trapped, again with relevance for working out the effects of global warming today. It can even be seen in the popular media as the multidisciplinary approach is reflected in the many competing factors (from impacts and volcanoes to faunal and disease interchanges due to shifting continents) offered in a *History Channel* science program *The First Apocalypse* (aired in January 2009), or the chapter Bill Nye (2014, 102-113) devoted to the extinction issue.

How far a cry is this from creationists like Eric Lyons (2010a) of *Apologetics Press*, who didn't even get as far as Thomas and *AiG*, though, finding it easier to dismiss an Internet account of the debate over the role of the K-T impact rather than dive into the technical literature and show they can making sense of the evidence relating mass extinctions vs. background extinction processes within their own model.

And how much farther still is this from the "scientific" Phillip Johnson over in Intelligent Design land, trying not to understand mass extinctions as a natural phenomenon at all, but bringing them up solely as a blunt instrument to beat back the perceived threat of Darwinian evolution?

1.2 Section 3—Studying the Big Five mass extinctions reveals some recurring geological causes.

Although mass extinctions took place a long while ago, if you think such investigations are merely academic speculation—of no more relevance than "who let the dogs out" (as the obnoxiously popular song put it back in the 1990s)—you'd be quite wrong, for whatever answer might eventually carry the day could have profound implications for how we think about our living ecosystem today. Why? Because if mass extinctions have natural causation, whether one or several, identifying those factors have relevance in determining whether or not we might be *artificially* engineering comparably unstable conditions today. No one wants to be on the wrong end of the extinction curve, or trying to get by when the larger biological systems start crashing around you.

By the standard of loss of biodiversity covered by Şengör *et al.* (2008) our present human driven losses threaten to exceed even the K-T event levels. Which is part of the reason why modern scientists study the PETM as they do for the lessons it may hold as an analog for our own greenhouse warming activities, Bowen *et al.* (2006). Likewise for the Triassic mass extinction over a hundred million years earlier still, as it occurred during a period of global warming directly involving a significant rise in atmospheric carbon dioxide. As this wasn't due to industrializing dinosaurs, but rather from things like the magma plume and the Pangea supercontinent breaking up, it gives us a measure of how potentially momentous (and dangerous for particular critters, like *us*, all too dependent on our monoculture food crops) entirely natural fluctuations can be. While plant life didn't crash in the way animals did then, McElwain *et al.* (1999; 2009) tracked how the abruptly warming climate nonetheless caused significant turnover in the ecology and diversity of the survivors, and the correlation between high global temperature and both the origination and extinction rates of animals is remarkably consistent over the last 520 million years, Mayhew *et al.* (2008).

The current debate over human-inspired climate change is entangled with a lot of very familiar cultural and methodological baggage, where many of the same people who express intractable skepticism over global warming happen to be equally certain that natural evolution flies against "scientific" reason and evidence. This track includes more traditionally religious YEC apologists like Jerry Falwell (1933-2007) and today's Hank Hanegraaff but intersects with the ID orbit via the many interview opportunities provided by members of the *Discovery Institute*, who are just as happy to appear on Hanegraaff's *Bible Answer Man* to criticize global warming or evolution as they are to provide background antievolution briefings for the popular conservative harpy Ann Coulter.

The problem science inevitably poses for the ideologically driven tortucan mind is that the scientific process can't help generating such chains of implication. That is, it will do so provided it sticks close to the truth, for there has always been a *fecundity* about notions that are actually so. They lead to fresh discoveries and insights, which do not become less true or relevant just because some people find the conclusions unpalatable.

A dandy example jumps at us from way back in the Cretaceous: *did* the dinosaurs become extinct in the K-T event? Had birds evolved from theropod dinosaurs (the bipedal predators and their kin), as opposed to some earlier thecodont reptile (regarded as earlier cousins of those archosaurs ancestral to the dinosaurs)? This is no taxonomical hairsplitting, for if birds are indeed the living descendants of dinosaurs, their present behavior and fundamental genetic structure provide invaluable clues in deciphering the nature of their extinct brethren, animals thought permanently beyond the reach of direct investigation.

Understanding the true nature of dinosaurs is thus inextricably linked to working out their correct evolutionary history. Presuming, of course, they *had* an evolutionary history to begin with, for at just the time that I was diving into dinosaur paleontology again, creationists were also swinging into high gear in their effort to persuade the secular community that everything about evolutionary theory was an egregious crock, entirely unsupported by the "true facts" of science.

Here, then, was quite a test for me. If the creationists' view of natural history was the correct one, should they not be able to account for such matters as the dinosaurs with greater clarity and explanatory power than their evolutionary opponents? Their version should have about it what physicist Philip Morrison (1915-2005) has dubbed "the ring of truth." Such is the resonance of all genuine knowledge.

From the evolutionary side, paleontologists like David Norman were explaining the specific development of dinosaurian musculature over time, and exploring the coevolutionary relationship between the jaw structure of herbivorous dinosaurs and the changing nature of the plants they were eating. You see how easy it is to get deep into the technical issues when you're dealing with real live scientific investigation.

Meanwhile, what were the gems of insight being offered apropos the dinosaurs by the renascent creationists? Well, they *must* have been on Noah's Ark, you see, for according to the Bible all land animals had been thus included. Some theorists ventured even further, insisting on scriptural authority alone that only subsequent to the Flood had carnivory entered the animal kingdom at all, which meant those carnosaurs conventional paleontology erroneously viewed as ferocious predators had in fact been initially docile herbivores, living amiably beside Adam and Eve in the Garden of Eden.

Let's not put too fine a point on this. What I was hearing from the creationist community in the early 1980s about dinosaurs was arrant drivel. There was no physical evidence that dinosaurs and people coexisted in any sense whatsoever, while claims about the presumed plant eating characteristics of tyrannosaurs flew in the face of everything that had been learned about comparative anatomy over the last few centuries. And in furtherance of this Flintstones version of paleontology, creationists were actively bullying legislatures and school boards to adopt this nonsense as though it were credible science. Clearly my high school physics teacher's benign "ice canopy" theory had in the meantime grown sharp teeth indeed.

And that is how my childhood interest in dinosaurs led first to my following the creation/evolution debate, and ultimately escalated into my writing this present volume. The more I studied what creationists were asserting, the more discordant their worldview appeared in contrast to the real science I could observe regarding not only the dinosaurs, but everything else in the natural world. Instead of that "ring of truth," what I was getting from creationism was a very dull thud.

But all this resounds very differently to creationists, and therein lays the crux of the problem. While evolutionists are talking "science," creationists are really addressing serious social concerns. For them, evolutionary theory is not about discovering to what extent the herbivorous iguanodontid dinosaurs differentiated from the earlier camptosaurids during the Cretaceous; it is a battle to expunge what they perceive as the pervasive corruption of a modern secular age that has fallen away from the Revealed Word of God. Creationists are concerned not about the morphology of Permian reptiles, but about teenage pregnancy, abortion, and homosexual rights. Their struggle against evolution is part of a much larger culture war (a *Kulturkampf*, to borrow a handy term left over from Bismarck's "cultural struggle" with parochial education during the formation of the old German Empire) and cannot be understood apart from that context.

The problem for science is that in the pursuit of this social agenda creationists jettison the common practices of scholarly method. Sources are read for ammunition, not understanding. Relevant information is misrepresented or ignored altogether. It is this aspect of the creationist enterprise that is potentially so destructive, for no legitimate discipline (let alone science) can be sustained for long on methodological foundations so sloppy as that lying at the heart of creationist thinking.

But there is some utility to come from all this: creationists (and their latest Intelligent Design iteration) have been so mind-bogglingly verbose, speaking and writing so much for so long that they have generated a trail that illustrates with amazing clarity what is (and just as importantly, what is not) going on in their heads. It is that diagnostic aspect that is the target of *Troubles in Paradise*.

Now you might well ask, if creationists are truly such transparent blockheads heaven-bent to lead the millions straight off the cliff of pseudoscience, what does this bode for the American Republic, given that their views are accepted by roughly half the population (reflected in varying degree among their elected officials) and even about a quarter of public school science teachers?

That is the fact, after all: the polling data are quite consistent here, showing that my old high school physics teacher is by no means anomalous. With only minor fluctuations, year on year, the American public sustains a belief that natural evolution is not true at a level comparable to the public acceptance of astrology or UFOs—roughly 45% of Americans are friendly to the idea that the Earth is only around 6000 years old and that there were dinosaurs on Noah's Ark. This is not as high as some creationists imagine, though, such as the optimistic George Grebens (2005) claiming (without supporting citation) that "over 65% of the American population adheres to the creation interpretation of origins, worldwide Flood and geological evidence for catastrophism."

Still, the actual value of around 45% have shown very little adjustment based on the efforts of the secular educational process. The lack of significant shifts in views may be traced via Ecker (1990,10), Eve & Harrold (1991, 4, 32, 163-166), McKown (1993, 65n), Zimmerman (1991) surveying legislators in Ohio and Congress, Brown (2002, 280), Branch (2004), Duncan & Geist (2004), Plutzer & Berkman (2008), *Angus Reid* (2010), *Virginia Commonwealth* (2010), Bishop *et al.* (2010) analyzing a recent *Harris Poll* (2009), and Newport (2010) digesting the modestly undulating Gallup Poll surveys taken since 1982. The *National Center for Science Education* (NCSE) keeps up with the polling data, by the way, providing useful updated links at *ncse.com*.

Rosenau (2013d) has thrown up a caveat, though: that if you tease out the contentious issue of *human* evolution from the polling data there may be fewer doctrinal Young Earth believers in the mix than appears to be the case depending on his the questions are framed, and given the prominence of human origins as a hot button concern of antievolutionists, explored in **Chapter 5** of Downard (2004), this may indeed be true—a similar factor was spotted in the subpopulation review of creationist beliefs by Duncan & Geist (2004), where 82% had problems with human evolution. But as a practical matter it may not be workable to keep the human side of things sealed off long enough in the educational process to satisfy the sensibilities of some potential evolution believers, in the cheery hope that, if only they can be sold on trilobites evolving or continents slogging along, they can be weaned onto the big evolutionary picture—not given the fact that modern scientific thinking includes us in the evolutionary mix as a matter of course and that particular shoe will have to drop eventually.

A measure of a bit of a demographic shift recently is a 2017 Gallup poll, Swift (2017), which showed a drop in the camp that believed humans were created in the last 10,000 years, to a historic low of 38% (a lot of those apparently moving to an evolved with God's help position), along with an equally high value of 19% for those believing in human evolution without any God involvement at all. The traditional *Kulturkampf* contingent was still in evidence, though, when you looked at the groups based on church attendance (where 65% of weekly attendees were in the YEC camp), denomination (half of the Protestants and 37% of Catholics), and education (48% for high school or less education). For comparison, 57% of those indicating no religious preference fell into the purely natural evolution camp.

Compound that with the occurrence of creationist school teachers and you have yet another hurdle to jump. Teachers reflected the popular creationist sympathy of the general population when it came to supporting "equal time" public school instruction: Ellis (1986), Schick & Vaughn (1999, 6-7) or Weld & McNew (1999), with Aguillard (1999, 185) specifically on Louisiana. It is hardly surprising then that creationist-friendly primary and secondary school instruction can ripple down up educational food chain to one degree or another, reflected in the polling of college students at secular and religious institutions undertaken by Cole (1987), Moore & Kraemer (2005) and Moore *et al.* (2009) regarding Minnesota (this in spite of the state having a fairly strong pro-evolution science teaching standard), and various broader surveys by Bowman (2008), Moore & Cotner (2009) and Paz-y-Miño C. & Espinosa (2009a-b)—in turn rebounding again to the extent that college students retaining mistaken notions about the evolutionary process later take up teaching as a vocation.

The situation has remained strikingly impervious to progress via education, as Matt Young (2011a) noted in a review of Berkman & Plutzer (2010), or Lauri Lebo (2011g) concerning further polling. Recent repackaging of the religious approach under the Intelligent Design rubric (whereby genetic change and some degree of common descent can be accommodated somehow or other within an otherwise God-directed scenario) has only reinforced the dynamic: while 16% of the high school biology teachers surveyed by Berkman *et al.* (2008) identified themselves as explicit YEC creationists—dropping a bit to 13% in Berkman & Plutzer (2011)—a much larger 47% characterized themselves in 2007 as believing in Intelligent Design, so that the combined "teach the controversy" evolution skepticism camp of 63% far outweighed the 28% core of teachers declaring themselves to be full-blown evolutionists. The survey by Randy Moore (2007) is consistent with this shift, as was Bowman (2008) finding "intelligent design" almost twice as likely (34%) to be treated as a viable scientific concept in public school science classes than "creationism" (18%).

This shouldn't really come as a complete shock, though. Part of the acceptance of creationism simply reflects the fact that cultures get what they value, and lots of Americans (including those who end up as high school science teachers) believe the Bible is true and that is that. But there is more to it than simply demographic reality. Cultures get *exactly* what they value. Not what they *profess* to value, but what they *actually* value, and beyond the parochial articulation of a broadly held religious culture lies a more general human reluctance to do the hard work required to temper their convictions with firm reasoning.

In a blunt nutshell: there is a natural laziness that reinforces many of our deeply held misbeliefs. It is much easier to believe something that is congenial than it is to seriously work out whether the evidence warranted your believing it in the first place. We'll see this aspect popping up in some interesting places, from the vituperative oeuvre of political pundit Ann Coulter to the avalanche of derivative claptrap spewed (and there is no more accurate word for it) in the *dozens* of incredibly repetitive books and websites generated by the indefatigable Turkish creationist Adnan Oktar (who writes under the pseudonym "Harun Yahya").

The propensity of the likes of Coulter and Yahya to funnel parasitically the misinformation of others only mirrors a larger tendency for people to take their "facts" in manageable doses provided it tastes right. To see a graphic illustration of this just consider out what gets stocked in the checkout line at grocery stores. While you will see *National Geographic* and *Scientific American* alongside the decorating, sports and gaming titles in the magazine section, tucked back by produce or gift cards usually, the checkout line is targeted to a more specialized mass appeal impulse buyer, and there you will not see the current issue of the *Proceedings of the National Academy of Sciences* (PNAS for short).

Instead there is a gauntlet of celebrity and soap opera guides, along perhaps with a scattering of gaudy tabloid papers proclaiming yet another amazing revelation from the Dead Sea Scrolls, next to the latest Elvis and Bigfoot sightings. These papers exist only because the public continues buying them. Quite apart to whether they believe any of it, their existence testifies to how much they are *valued*.

Or consider the popularity of astrology columns in daily newspapers. Even by the standards of professional astrologers—let alone the scientific critics who disassemble their every presumption, such as Carlson (1985)—the general horoscope based only on the sun sign cannot possibly have any relevance beyond chance, yet they persist because the devouring public finds them entertaining or comforting. They perform a reassuring social function, which is not about to be vitiated merely on account of it not being even slightly true. Indeed, this remains so even among the public who profess a scientific worldview (including belief in evolution) who tend to be *more* willing to follow astrology columns than do religiously devout creationists. Orenstein (2009) speculates this may be so because the creationist is in a sense inoculated against flirting with a lot of outside activities deemed inappropriate (such as the demonic occult that would include astrology) while the more open-minded popular science aficionado jumps in feet first.

I contend that the behavior that Orenstein was lamenting is just a manifestation of what it means to have a large population of tortucans knocking around, but the phenomenon is hardly a new trend. As the congenitally cynical H. L. Mencken (1880-1956) accused back in the 1920s, no one ever lost a dime underestimating the intelligence of the American public. Jay Leno tread the same turf in his running "Jaywalking" segment when he was at the helm of the *Tonight Show*, quizzing all-too-average people about what ought to be the common knowledge of history and culture. If one wants more scholarly verification, the National Constitution Center (1997; 1998) found a lack of depth in understanding the nuts and bolts of our Constitution. Sure, most could say who the President was and that the first 10 amendments are known as the Bill of Rights, but only 5% could pass all ten items on a "rudimentary" questionnaire about the Constitution. More to our point, a quarter of those surveyed thought our explicitly godless Constitution established Christianity as "the official religion of the US."

Thus the grocery store checkout line or the newspaper astrology columns of today only serve to measure an underlying stability of the human character that needs accounting for. The creationist is simply a big subset of a population that—no matter what they may profess to pollsters—doesn't in practice pay any ingrained attention to either the scientific literature or the methodology so essential to generating it.

Nor can we overlook social pressures. I doubt there is an American teenager alive who has not been made aware of the dangers of smoking—information keeps turning up to hone the tale of woe, for instance that second-hand smoke can act as a male reproductive mutagen, Marchetti *et al.* (2011). Yet the knots of underage puffers around public schools during breaks suggest there is indeed a functional limit to education when it has to compete with social convention—or even the dynamics of individual human neurobiology, as recently characterized by Kober *et al.* (2010) on the craving process inside our heads. Critics of creationism therefore must not delude themselves into thinking throwing just the facts at their target will serve to counteract the powerful social metaphysic that drives acceptance of (or at least toleration for and enabling of) a deeply pseudoscientific creationism that has the likes of Anne Coulter and Harun Yahya batting for it.

Add to this already potent stew the pedagogical phenomenon that most practicing scientists are not in the habit of having to explain, especially impromptu, the underlying historical and evidential logic of their discipline to outsiders—least of all to people with little or no grasp of the basic terminology involved. The typical geophysicist is too busy *using* radiometric dating to justify its validity to carping creationists asserting the contrary, and such confident but insufficiently articulated expertise appears to the argumentatively inclined believer as exactly the sort of blind arrogance their apologetic source books were warning them about.