

## ***Palaeontology, palaeobiology and evolution***

### **Verneshots (huge volcanic gas blasts) ten years on (*January 2015*)**

One of the most daring hypotheses of modern geosciences: is that of the '[Verneshot](#)' ( see [Mass extinctions and internal catastrophes](#) May 2004. Jason Phipps Morgan and colleagues explored the possible consequences of a build-up of volatiles in plume-related magmas at the base of thick continental lithosphere beneath cratons, prior to the eruption of continental flood basalts. They suggested that pressure would eventually result in an explosive release at a lithospheric weak point, followed by collapse above the plume head that would propagate upwards, at hypersonic speeds. Modelling the forces involved, the authors of the novel idea considered that they would be sufficient to fling huge rock masses into orbit. Verneshots might neatly explain the circumstances around mass extinctions, such as their coincidence with continental flood basalt events; large impact structures, most likely at the antipode of the event; global debris layers containing shocked rock, melt spherules; unusual element suites and compounds (including fullerenes); and enough toxic gas to cause biological devastation.

Ten years on, Verneshots are back, again in the prestigious journal *Earth and Planetary Science Letters*, and this time among the co-authors are Morgan *père et fils* (W. Jason a founder of plate tectonics, and Jason P. who launched the idea). This time the yet-to-be – accepted hypothesis comes with evidence of an extremely unusual and fortuitous kind (Vannucchi, P. *et al.* 2015. Direct evidence of ancient shock metamorphism at the site of the 1908 Tunguska event. *Earth and Planetary Science Letters*, v. **409**, p. 168-174; DOI: 10.1016/j.epsl.2014.11.001). The origin of the paper lies in an attempt to verify reports of shocked quartz in samples collected close to the centre of the 2000 km<sup>2</sup> devastation in the Tunguska region of Siberia that resulted from what is now accepted to have been a comet or asteroid air-burst explosion in June 1908. Apart from a disputed 300 m crater in the area, the Tunguska Event left no long-lived sign: it 'merely' knocked over millions of trees. However, its epicenter lay in a 10 km depression ringed by hills, that has been suggested to be a volcanic centre associated with the end-Permian [Siberian Traps](#).

The reported shocked quartz locality turned out to associated with an isolated occurrence of quartz-rich sand and rounded clasts of quartzite that contains sedimentary structures. The occurrence is surrounded by basalts of the Siberian Traps, yet is situated topographically above them. The quartzite is thought to be Permian terrestrial sandstone that commonly underlies much of the remaining extent of Siberian Traps.

Quartzite clasts do indeed contain shocked quartz, together with pseudotachylite glass veinlets, quartz and feldspar crystal growth on sedimentary grains and silica-rich glassy spherules. These features are not uniquely diagnostic of shock metamorphism, but are oddly absent from the surrounding Siberian Traps nearby, which suggests that whatever formed them predated the final eruptive stages of the end-Permian large igneous province. Indeed it would be unlikely that airburst of some extraterrestrial bolide in 1908 could produce the metamorphic features of the quartzites without setting ablaze the trees that it felled. A second possibility, that the Tunguska Depression is a Permo-Triassic impact crater and the quartzites being part of an associated central uplift runs into the unlikely coincidence of lying less than 5 km from the 1908 epicentre.



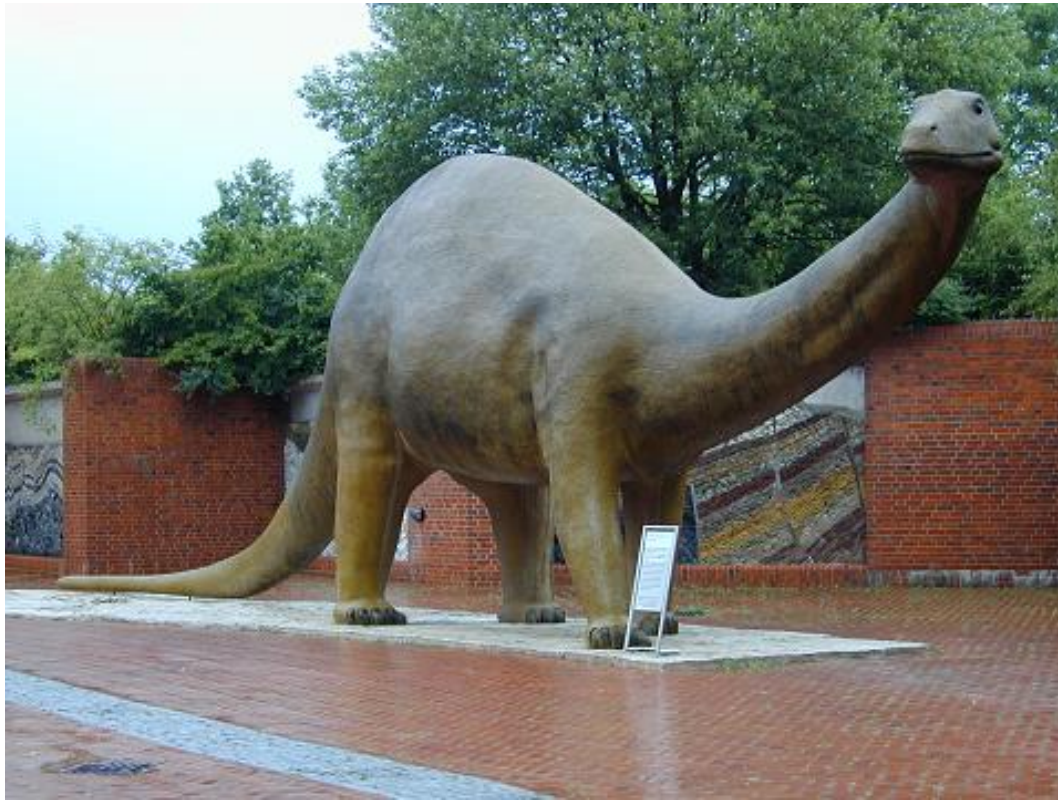
Trees knocked down and burned over hundreds of square km by the 1908 Tunguska Event (credit: Leonid Alekseyevich Kulik deceased)

A third hypothesis is that the Tunguska Depression is a massive diatreme associated with a Verneshot. Another odd association lies 8 km to the south of the epicentre, a carbonatite that is one of many, along with smaller pipe-like structures all possibly linked to magmatic gas escape. The Tunguska Event, a mighty puzzle in its own right, may perhaps be eclipsed. Will silence return as it did after the original Verneshot hypothesis was published? Quite possibly, but another quirk about the Siberian Traps was reported by Earth Pages in mid-2014. In a contribution to a link between this massive end-Permian volcanic effusion and the [Permian-Triassic mass extinction](#) it was noted that in the Chinese sedimentary repository of evidence for the extinction there is an isolated spike in the abundance of nickel (see [Nickel, life and the end-Permian extinction](#) June 2014) that is almost certainly of volcanic origin, but only the one when repeated flood basalt events perhaps ought to have led to a series of nickel anomalies. One huge volcanic gas release as the Siberian Traps were building up?

### **The dinosaur they could not kill: *Brontosaurus* is back (April 2015)**

It would be pretty safe to say that everyone has heard of *Brontosaurus*, but in the 1970s the genus vanished from the palaeobiology lexicon. The '[Bone Wars](#)' of post-Civil War US palaeontology stemmed from the astonishing prices that dinosaur skeletons fetched. The frenzy of competition to fill museums unearthed hundreds of specimens, but the financial enthusiasm did not extend to painstaking anatomy. Finding a new genus meant further profit so a slapdash approach to taxonomy might pay well. So it did with the dinosaur family [Diplodocidae](#) for [Othniel Marsh](#), one of the fossil marauders. He along with his main competitor, Edward Cope, was a wizard fossicker, but lacked incentive to properly describe what he unearthed. In 1877 Marsh published a brief note about a new genus that he called *Apatosaurus*, and then hurried off for more booty. Two years later he returned from the field with another monster reptile, and casually made a brief case for the 'Thunder Lizard', *Brontosaurus*. Unlike his usage of 'Deceptive Lizard' for *Apatosaurus*, the English translation

of *Brontosaurus* caught the public imagination and lingers to this day as the archetype for a mighty, extinct beast. Yet, professional palaeontologists were soon onto the lax ways of Marsh and Cope, and by 1903 deemed *Brontosaurus* to be taxonomically indistinguishable from *Apatosaurus*, and as far as science was concerned the 'Thunder Lizard' was no more.



Replica of Brontosaurus (credit: Museum für Naturkunde, Münster Germany)

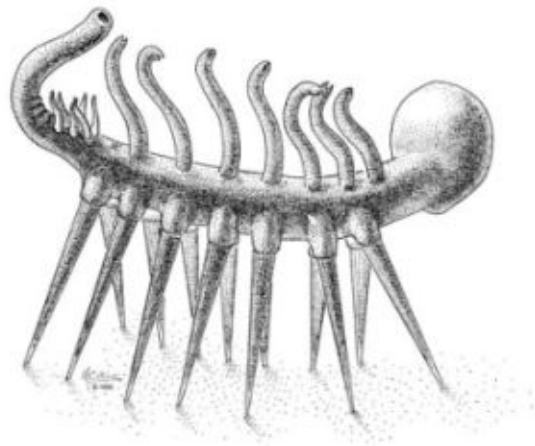
But the legacy of frenzied fossil collecting of a century or more ago is huge collections that never made it to display, which form rich pickings for latter-day palaeontologists with all kinds of anatomical tools now at their disposal: the stuff of almost endless graduate studies. Emanuel Tschopp of the New University of Lisbon with colleagues took up the challenge of the Diplodocidae by examining 49 named specimens and 32 from closely related specimens as controls, measuring up to 477 skeletal features (Tschopp, E. *et al.* 2015. A specimen-level phylogenetic analysis and taxonomic revision of Diplodocidae (Dinosauria, Sauropoda). *PeerJ*, v. **3**, DOI: 10.7717/peerj.857). An unintended consequence was their discovery that 6 specimens of what had become [Apatosaurus excelsus](#) (formerly Marsh's *Brontosaurus*) differed from all other members of its genus in 12 or more key characteristics. It seems to taxonomists a little unfair that *Brontosaurus* should not be resurrected, and that looks likely.

Had this been about almost any other group of fossils, with the exception perhaps of the ever-popular tyrannosaurs, the lengthy paper would have passed unnoticed except by specialist palaeontologists. In a little over a week the open-access publication had more than 17 thousand views and 3300 copies were downloaded, despite the PDF's great size.

**See also:** Balter, M. 2015. Bully for Brontosaurus. *Science*, v. **348**, p. 168; DOI: 10.1126/science.348.6231.168.

## Hallucigenia gets a head (July 2015)

The Middle Cambrian [Burgess Shale](#) of the Canadian Rockies is one of those celebrated sediments that show extraordinary preservation of soft-bodied and easily disarticulated organisms and rich assemblages of fossils. Being one of the earliest known of such lagerstätten, many of the denizens of the ecosystem in which the shale originated were at first regarded as members of hitherto undiscovered and now vanished phyla, the basal branches of the 'tree of life'. Some certainly looked pretty odd, such as *Opabina* with a feeding apparatus looking similar to the extension nozzle of a vacuum cleaner; but that is clearly some kind of arthropod. Others turned out to be astonishingly large, once it was realised that parts of their broken bodies had previously been taken to be different organisms, an example being *Anomalocaris*. But perhaps the oddest, certainly to palaeontologists, was [Hallucigenia](#). However, there are plenty of even more weird and wonderful living creatures, such as the [sea pig](#), although modern creatures are more easily pigeonholed, taxonomically speaking.

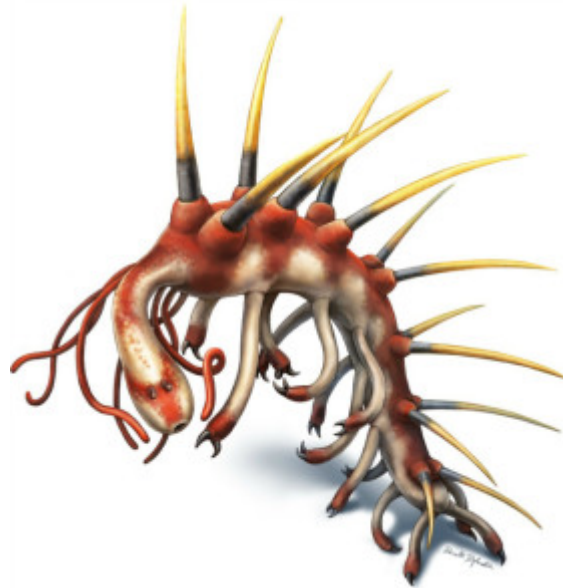


Hallucigenia as originally reconstructed; i.e. upside-down. (Credit: palaeos.com)

The trouble with *Hallucigenia* was not so much its complexity – it was a fairly simple-looking beast – but that there were two choices as to which way up it lived; a feature that surprisingly led to a great deal of pondering that ended with the scientist who formally described it in 1977 making the wrong choice. That was eventually resolved fourteen years later, but the creature might also have inspired [the Pushmi Pullyu](#) in Hugh Lofting's Dr Doolittle stories for children. Not that it resembled a unicorn-gazelle cross: far from it, for no-one could decide which its front was and which its backside, and even if it may have lain on its side. But *Hallucigenia* does demonstrate bilateral symmetry beautifully – it *must* have a front and back, and a top and bottom, even though which was which remained veiled in mystery – and so belongs to the dominant group of animals, imaginatively known as [bilaterians](#).

The Burgess Shale lagerstätte seemingly was heaving with *Hallucigenia* so would-be taxonomists have had no shortage of specimens to ponder over in the 38 years since [Simon Conway Morris](#) made his dreadful mistake: of course, that was not of such enormity as others in every discipline, and Conway Morris quickly accepted his error when the beast was turned right-way-up in 1991. The problem is, exquisite as they are, Burgess Shale fossils are flattened and all that remains of mainly soft-bodied animals are delicate carbonaceous films, which need electron microscopy to unravel.





The latest reconstruction of *Hallucigenia*, by palaeontological illustrator [Danielle Dufault](#) In 2015, *Hallucigenia*'s front end was definitely found, and a great deal more besides, by Canadian palaeontologists Martin Smith and Jean-Bernard Caron of the Royal Ontario Museum and the University of Toronto (Smith, M.R. & Caron J.-B. 2015. *Hallucigenia*'s head and the pharyngeal armature of early ecdysozoans. *Nature*, v. **523**, p. 75-78; DOI: 10.1038/nature14573). It has eyes, albeit rudimentary, and a throat, deep within which it has pointy teeth. *Hallucigenia* was a [lobopod](#), whose living relatives lie within that large and diverse group the [Ecdysozoa](#), which all have throat teeth and include the wondrous water bear (tardigrade) and the velvet- and penis worms (onychophores and priapulids, respectively) as well as lobsters, flies and woodlice. It may indeed have been close to the last common ancestor of all those animals that moult their carapaces.

**Related article:** [Tiny, 'fierce' B.C. fossil find \*Hallucigenia\* had 'lovely smile,' ring of teeth and a head mistaken for its tail](#) (nationalpost.com)

### **Pleistocene megafaunal extinctions – were humans to blame? (August 2015)**

Australia and the Americas had an extremely diverse fauna of large beasts (giant wombats and kangaroos in Australia; elephants, bears, big cats, camelids, ground sloths etc in the Americas) until the last glaciation and the warming period that led into the Holocene interglacial. The majority of these megafauna species vanished suddenly during that recent period. To a lesser extent something similar happened in Eurasia, but nothing significant in Africa. Because the last glacial cycle also saw migration of efficient human hunter-gatherers to every other continent except Antarctica, many ecologists, palaeontologists and anthropologists saw a direct link between human predation and the mass extinction (see [Large animal extinction in Australia linked to human hunters](#) April 2012. Earlier humans had indeed spread far and wide in Eurasia before, and the crude hypothesis that the last arrivals in Australasia and the Americas devoured all the meatiest prey in three continents had some traction as a result. Predation in Eurasia and Africa by earlier hominids would have made surviving prey congenitally wary of bipeds with spears. In Australia and the Americas the megafauna species would have been naive and confident in their sheer bulk, numbers,

speed and, in some cases, ferocity. Other possibilities emerged, such as the introduction of viruses to which faunas had no immunity or as a result of climate change, but none of the three possibilities has gained incontrovertible proof. But the most popular, human connection has had severe knocks in the last couple of years. A fourth, that the extinctions stemmed from a [comet impact](#) ( see [Comet slew large mammals of the Americas](#) March 2009) proved to have even less traction.



Megafauna in a North American late-Pleistocene landscape including woolly mammoths and rhinoceroses, horses, and large cats. (Credit: nwtexhibits.ca)

Since the amazing success of analysing the bulk DNA debris in sea water – environmental DNA or eDNA – to look at the local diversity of marine animals, the analytical and computing techniques that made it possible have been turned to ancient terrestrial materials: soils, permafrost and glacial ice. One of the first attempts revealed mammoth and pre-Columbian horse DNA surviving in Alaskan permafrost, thanks to the herds' copious urination and dung spreading (see [Some megafaunas of the recent past](#) May 2011). Several articles in the 24 July 2015 issue of *Science* review advances based on ancient DNA, including eDNA from soils that chart changes in both fauna and flora over the last glacial cycle (Pennisi, E. 2015. Lost worlds found. *Science*, v. **349**, p. 367-369; DOI: 10.1126/science.349.6246.367). Combined with a variety of means of dating the material that yield the ancient eDNA, an interesting picture is emerging. The soil and permafrost samples potentially express ancient ecosystems in far more detail than would fossil animals or pollens, many of which are too similar to look at the species level and in any case are dominated by the most abundant plants rather than showing those critical in the food chain.

The first major success in palaeoecology of this kind came with a 50-author paper using eDNA 'bar-coding' of permafrost from 242 sites in Siberia and Alaska (Willerslev, E. and 49 others 2014. [Fifty thousand years of Arctic vegetation and megafaunal diet](#). *Nature*, v. **506**, p. 47-51; DOI: 10.1038/nature12921).





Plants of the Arctic tundra in Nunavut, Canada (Credit: Flickr)

Dividing the samples into 3 time spans – 50-25, 25-15 (last glacial maximum) and younger than 15 ka – the team found these major stages in the last glacial cycle mapped an ecological change from a dry tundra dominated by abundant herbaceous plants (forbs including abundant anemones and forget-me-not), to a markedly depleted Arctic steppe ecosystem then moist tundra with woody plants and grasses dominating. They also analysed the eDNA of dung and gut contents from ice-age megafauna, such as mammoths, bison and woolly rhinos, where these were found, which showed that forbs were the mainstay of their diet. Using bones of large mammals 6 member of the team also established the timing of extinctions in the last 56 ka (Cooper, A. *et al.* 2015. Abrupt warming events drove Late Pleistocene Holarctic megafaunal turnover. *Science*, DOI: 10.1126/science.aac4315), showing 31 regional extinction pulses linked to the rapid ups and downs of climate during [Dansgaard-Oeschger cycles](#) in the run-up to the last glacial maximum. By the end of the last glacial maximum, the megafauna were highly stressed by purely climatic and ecological factors. Human predation probably finished them off.

### **Deccan Trap sprung by bolide? (October 2015)**

It was 35 years back that father and son team Luis and Walter Alvarez upset a great many geoscientists by suggesting that a very thin layer of iridium-rich mud that contained glass spherules and shocked mineral grains was evidence for a large meteorite having struck Earth. They especially annoyed palaeontologists because of their claim that it occurred at the very top of the youngest Cretaceous and that the mud was spread far and wide in deep-

and shallow-marine stratigraphic sequences and also in those of continental rocks. It marked the boundary between the Mesozoic and Cenozoic Eras and, of course, the demise of the dinosaurs and a great many more, less 'sexy' beasts. Luis was a physicist, his son a geologist and their co-researchers were chemists. It can hardly be said that they stole anyone's thunder since the issue of mass extinctions was quiescent, yet their discovery ranks with that of Alfred Wegener; another interloper into the closed-shop geoscientific community. They got the same cold-shoulder treatment, but massive popular acclaim as well, even from a minority of geologists who welcomed their having shaken up their colleagues, 15 years after the last 'big thing': plate tectonics. And then the actual site of the impact was found by geophysicists in a sedimentary basin in the Gulf of Mexico off the small town of Chicxulub on the [Yucatan peninsula](#).



Chicxulub impact – artist impression (credit: NASA)

As they say, 'the rest is history' and a great many geoscientists didn't just jump but hurled themselves on this potential bandwagon. Central to this activity was the fact that, within error, the ages of the impact, the mass extinction and a vast pile of continental lavas in western India, the [Deccan Traps](#), were more or less the same (around 66 Ma). Flood basalt events are just about as dramatic as mega-impacts because of their sheer scale, involving of the order of a million cubic kilometres of magma; that they were exuded in a mere million years or so, but in only a few stupendous lava flows; and they are far beyond the direct experience of humans, blurring out only every 30 Ma or so. This periodicity roughly tallies with mass extinctions, great and small, during the Mesozoic. There have been two large bands of enthusiasts engaged in the causality of the end-Mesozoic die-off – the extraterrestrials and the parochialists who favoured a more mundane, albeit cataclysmic snuffing-out. Mass extinctions in general have been repeatedly examined, and in recent years it has become clear that most of those since 250 Ma ago seem to be associated with basalt-flood events and are purely terrestrial in origin. As regards the event that ended the Mesozoic, it has proved difficult to resolve whether to point the finger at the Deccan Traps or the [Chicxulub impact](#). Both might have severely damaged the biosphere in perhaps different ways, so a 'double whammy' has become a compromise solution.





Deccan flood basalts of the Western Ghats in Maharashtra, India

Unsurprisingly, a lot of effort from different quarters has gone into charting the progress of the Deccan volcanism. Some dating seemed at one stage to place the bulk of the volcanism significantly before the mass extinction and impact, others had them spot on and there were even signs of an hiatus in eruptions at the critical juncture. The problem was geochronological precision of the argon-argon method of radiometric dating that is most used for rocks of basaltic composition: many labs cannot do better than an uncertainty of 1%, which is  $\pm 0.7$  Ma for ages around the end of the Mesozoic, not far short of the entire duration of these huge events. Some Deccan samples have now been dated to a standard of  $\pm 0.1$  Ma by the Ar-Ar lab at the Department of Earth and Planetary Sciences, University of California-Berkeley (Renne, P.R. *et al.* 2015. [State shift in Deccan volcanism at the Cretaceous-Paleogene boundary, possibly induced by impact](#). *Science*, v. **350**, p. 76-78; DOI: 10.1126/science.aac7549). The results, between 65.5 to 66.5 Ma, nicely bracket the K/T (now K/Pg) boundary age of  $66.04 \pm 0.04$  Ma. It looks like the double whammy compromise is the hypothesis of choice. But there is more to mere dating.

Renne and colleagues plot the ages against their position in the volcanic stratigraphy of the Deccan Traps in two ways: against the estimated height from base in the pile and against the estimated volume of the erupted materials as it built up – the extent and thickness of successive flows varies quite a lot. The second plot provided a surprise. After the K/Pg event the mean rate of effusion – the limited number of individual flows capped by well-developed soils shows that the build-up was episodic – doubled from  $0.4 \pm 0.2$  to  $0.9 \pm 0.3$  km<sup>3</sup> yr<sup>-1</sup>. Despite the much larger uncertainty in the extent and volume of individual lava Formations than that of their ages, this is clearly significant. Does it imply that the Chicxulub

impact somehow affected the magma production from the mantle plume beneath the Deccan? It had been suggested early in the debate that the roughly antipodean position of the lava field relative to that of Chicxulub may indicate that the huge seismicity from the impact triggered the Deccan magma production. Few accepted that possibility when it first appeared. However, Renne and co. do think it deserves another look, at least at the possibility of some linked effect on the magmatism. Perhaps the magma chamber was somehow enlarged by increased global seismicity; other chambers could have been added; magma might have been 'pumped' out more efficiently, or a combination of such effects. The 'plumbing' of flood basalt piles is generally hidden, but huge dyke swarms in older terranes have been suggested as feeders to long-eroded flood basalts. Seismicity of the scale produced by asteroid impacts can do a lot of damage. The Chicxulub impactor at around 10 km diameter would have carried energy a million times greater than that of the largest thermonuclear bomb, equivalent to an earthquake of Magnitude 12.4. That would have been a thousand times more powerful than the largest recorded earthquake with tectonic causes. Extensional faulting sourced in this fashion in the Deccan area may have increased the pathways along which magma might blurt out.

#### Related articles

Duncan, R. 2015. Deadly combination. *Nature*, v. **527**, p. 172-173; DOI: 10.1038/527172a.