Paper A1

Mass extinctions and global warming: lessons from the past for our present and the future

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A lot has been written of late about global warming or climate change that is linked to anthropogenic activities like burning of fossil fuels and destruction of natural carbon sinks by deforestation. An Intergovermental Panel for Climate Change (IPCC) was set by the United Nations in 1988 to assess the scientifi information relevant to human-induced climate change and make recommendations for mitigation and adaptation to cope with its predicted damaging effects. The most significan contributor to global warming was attributed to the rapid rise of greenhouse gases, especially carbon dioxide and methane, generated by anthropogenic activities since the beginning of the industrial evolution. Some detractors deny this and say that it is global warming that is leading to the higher concentrations of greenhouse gases and not the other way round.

Climate modellers came to the fore with powerful computer simulations to create scenarios both local and global on what would be the possible effects for every degree of rise in average global temperature of the Earth. Most climate models stop at 5°C and beyond that we have to peer into the past and get our clues from what can be inferred from looking at life on Earth in those geological periods when global temperatures were higher than that at present (Lynas, 2008).

Five major mass extinctions have been detected in the Phanerozoic record of life in the past. They had been attributed to various causes that could roughly be grouped into either earthbound eg. glaciation, sea level change, volcanism and oceanic current disruption, or extraterrestrial eg. supernova radiations and bolide impacts. These mass extinctions occurred at the end of the Ordovician, Devonian, Permian, Triassic and Cretaceous (Raup & Sepkoski, 1982). Other less severe and more limited mass extinctions were also detected in the geological record such as at the end of the Jurassic and the Paleocene-Eocene boundary.

Global warming associated with greenhouse gases release had not been considered a prominent contributor until more recently. Chief amongst these are the warmer periods in the Earth's past icluding the Cretaceous, the Jurassic and the end-Permian. The longest lasting greenhouse episode occurred during the Cretaceous where global temperatures were on average 10 to 15°C higher and sea-levels were 200 m or more higher than today's reducing the land surface exposed to about 80% of what exist today (Skelton, 2003). Dinosaurs and alligators roamed the palm forests that grew up to Alaska in an ice-free Earth. Massive thicknesses of chalk were deposited in the warm shallow seas that covered much of the drowned land. The earth was sequestering a lot of carbon dioxide in the lush forests and chalky shells of marine plankton in response to the warming Earth. The presence of giant tempestites, however, tells of intense storms that left big hummocks (Ito et al., 2001) on the ocean floo that tells tales of ferocious hurricanes that were most intense when temperatures were highest in the mid-Cretaceous when carbon dioxide and greenhouse temperatures peaked. The pump was primed for the end-Cretaceous mass extinction as few of the ecosystems we know could survive the extreme temperatures for too long. This was mitigated because many of the plants and animals of the Cretaceous world had a long time to adapt to such high temperatures.

While the greenhouse effect was spread out over a long period in the Cretaceous, the better analogue for the rapid rise in global temperature would be the Palaeocene-Eocene thermal Maximum (PETM) event , that like other warming spikes always seem to be associated with deposition of anoxic black shales indicative of "ocean anoxic events' or OAEs (Jenkyns, 2003). A chief suspect of such catastrophic killing of the oceans is the release of methane hydrates (Kerr, 2000) that warm the climate so severely that the oceans cease to turn over properly leading to oceanic desertification Severe rainstorms and desert sandstorms in a warmer world could also transfer extra amounts of nutients from land to fertilise the oceans leading to worldwide algal blooms that poison the ocean.

The biggest OAE took place in the Jurassic when carbon dioxide concentrations leap to 1,000 ppm in the atmosphere pushing global temperatures to 6°C. It lead to the biggest mass extinction of the Jurassic-Cretaceous period apparently caused by hot volcanic magma intruding into ancient coal seams across thousands of kilometers of southern Africa (Svensen et al., 2005) to release greenhouse gases that accelerated global warming to strip the oceans of oxygen and killing their inhabitants.

The most devastating mass extinction was the end-Permian that wiped out over 95% of species living both on land and in water at that time. Carbon and oxygen isotope studies across the P-T boundary revealed that there was a very rapid warming of no less than six degrees that changed the Permian world from one that was full of life to a nearly lifeless one within about 10,000 years. The discovery of anomalously abundant soil materials washed into marine deposits in Italy (Sephton,2005) and elsewhere together with a signature 'fungal spike' (Visscher et al., 1996) indicated deforestration that left the land bare (Benton, 2003) with proliferation of fungus on rotting vegetation in the great die-off were caused by desertificatio as temperatures rose in tandem with carbon dioxide concentrations that reached four times higher than today's (Kidder and Worsley, 2004). It was boosted by a massive injection from the great outpouring of the Siberian floo basalts that also put poisonous sulphur dioxide and nitrous oxides into the atmosphere that came down as acid rain and wiped out many marine organisms drastically affecting the food chain . Oxygen levels dropped to 15% (Weidlich, 2003) killing off many larger land animals while global warming released an estimated 9,000 billion tonnes of methane from unfrozen gas hydrates into the atmosphere. The methane cloud could have been ignited to produce a fuel-air explosive effect (Ryskin, 2003) that nearly destroyed all terrestrial life on Earth. Methane at very high concentrations of 5,000 times background level in the end-Permian together with hydrogen sulphide from rotting organisms, could have destroyed the protective ozone layer allowing deadly UV radiation to bathe the Earth causing harmful mutations (Visscher, 2004). This was followed by a distinct 'coal

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gap' in the early to mid-Triassic showing that only sparse vegetation survived after the end-Permian extinction. It took 50 million years for the Earth to recover to the level of pre-extinction biodiversity from the disaster.

A sixth mass extinction is occurring at present and attributed to the destructive input from the human race hence its name the Anthropocene Mass Extinction. This extinction was already underway independent of global warming. Our very destructive species has pushed many plants and animals into extinction with our wanton destruction of the organisms and their habitats forcing more and more of them onto the margins of survival so that just moderate climatic changes will be sufficien to push them over the brink. Anthropogenic carbon dioxide release is at least a hundred times faster than the fastest rates of volcanic outgassing in the past. There would not be time for lifeforms to adapt and the tipping point might be just round the corner.

What can be done to put the brakes on anthropogenic global warming and how much time do we have to do it? Lynas (2008) has helpfully summarized the CO_2 targets we must achieve for the different degrees of warming we aim for in table form (Table1). The way to do it that he advocates is following Robert Socolow and Steve Pacala's (2004) "knocking in wedges" strategy that proposes that we do more with what we are already doing in the different wedges of fightin greenhouse gases emissions to achieve the targets necessary to give us a fightin chance of putting the brakes on global warming. We can figh but I'm not sure we can win.

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Table 1: Projected temperature rise based on carbon dioxide concentrations and actions needed to achieve the targets (after Lynas, 2008).

Degree change	Actual temperature	Action needed	CO_2 target
One degree	0.1 – l.0°C	Avoidance probably not possible	350 ppm (today's level is 380 ppm)
Two degrees	1.1 – 2.0°C	Peak global emissions by 2015	400 ppm
Threshold for carbon cycle feedback?			
Three degrees	2.1 – 3.0°C	Peak global emissions by 2030	450 ppm
Threshold for Siberian Methane feedback?			
Four degrees	3.1 – 4.0°C	Peak global emissions by 2050	550 ppm
Five degrees	4.1 – 5.0°C	Allow constantly rising emissions	650 ppm
Six degrees	5.1 – 6.0°C	Allow very high emissions	800 ppm