Mass extinction of species and climate change

Inherent in mass extinction events through the late Proterozoic and the Phanerozoic (from 680 million years ago) history are changes in the physical and chemical properties of the atmosphere, ocean and land inducing environment changes at a pace to which many species could hardly adopt. The best documented example to date is the 65 million years [Ma]-old K-T boundary asteroid impact and extinction event [1], but several other mass extinctions were associated with volcanic eruptions and asteroid/comet impacts) [2] (Figure 1). Instantaneous effects of impacts (initial fireball flash as the bolide enters the atmosphere, crater explosion, seismic shock, tsunami waves, incandescent ejecta, dust plumes followed by greenhouse gas release from carbon-rich limestone and shale occurred over periods ranging from seconds to weeks and months. As shown in figure 1 Phanerozoic history (since about 540 Ma) is marked with a number of mass extinction events, with genera loss of up to 80% at the ~251 Ma Permian-Triassic boundary event, a consequence of both volcanic eruptions (Siberian Norilsk traps) and an asteroid impact (Araguinha, Brazil) [3].

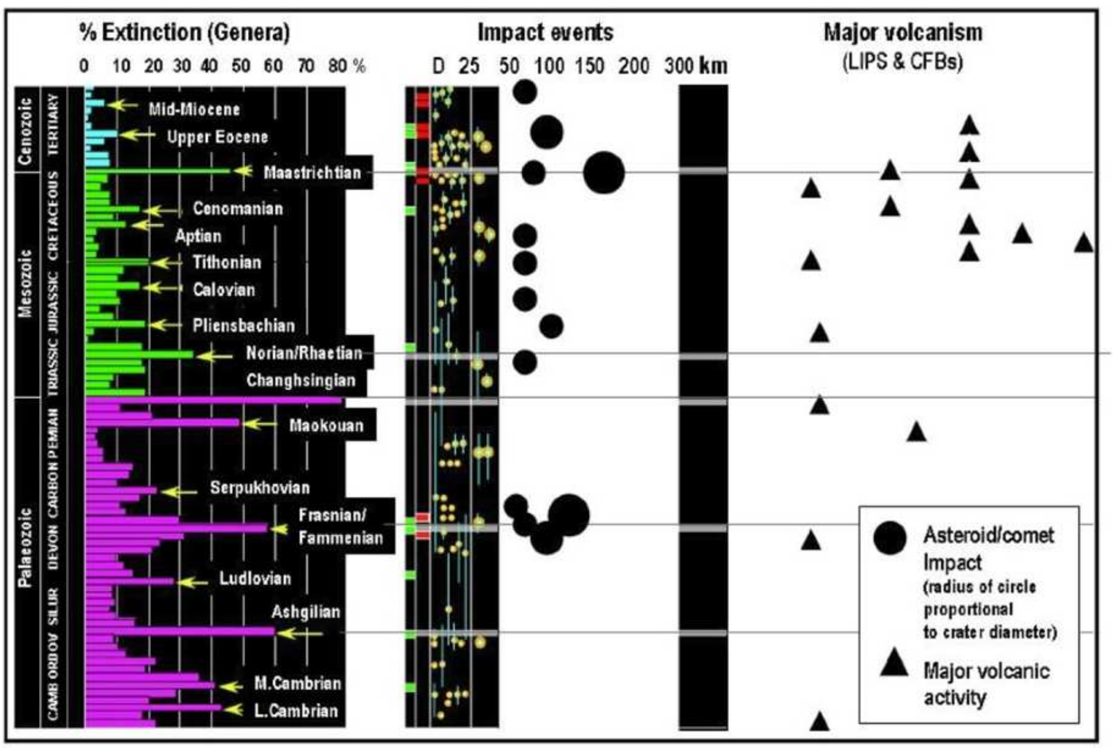

Figure 1. Phanerozoic genera extinction rates, extraterrestrial impact events (circles denote relative magnitude of impacts) and major volcanic events. Glikson, 2010, after Keller, 2005.

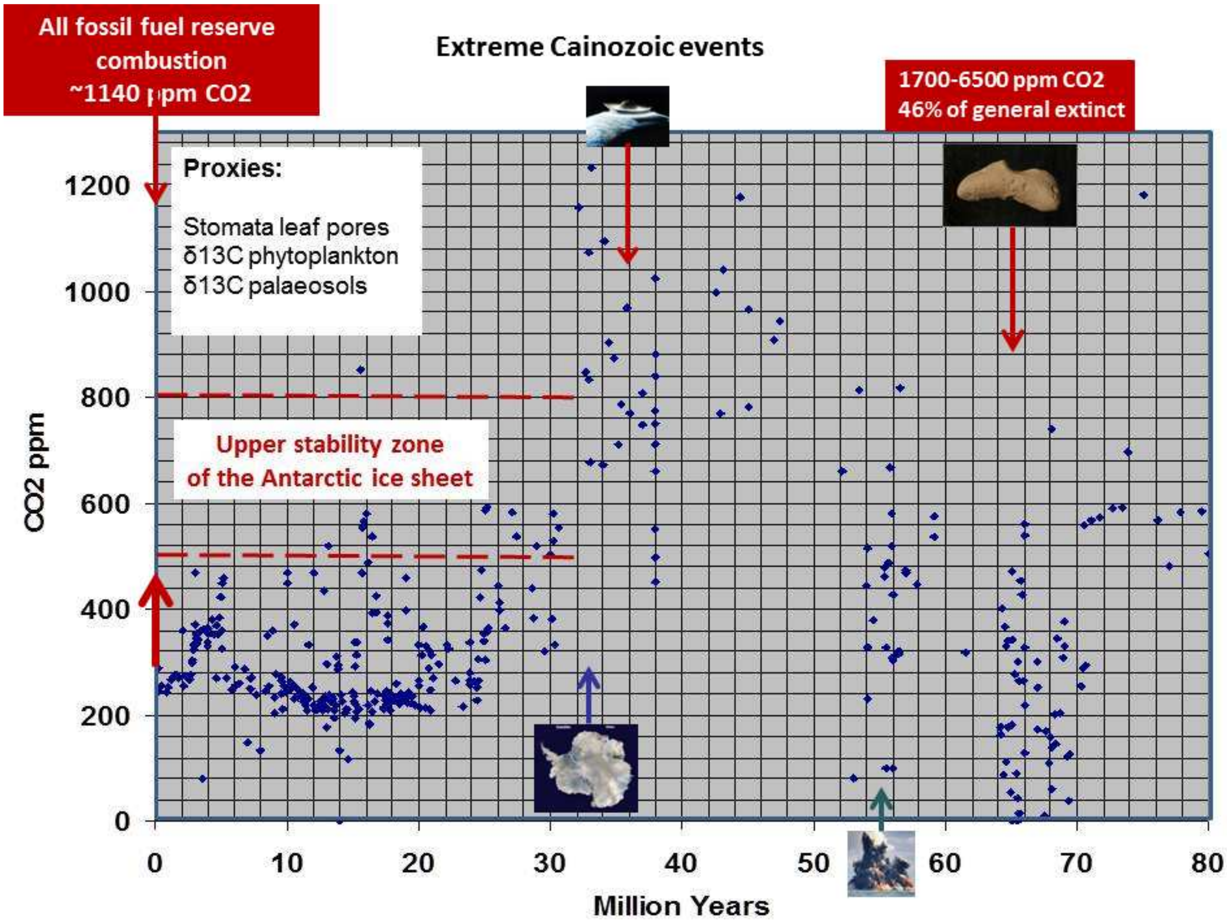

Figure 2. Evolution of atmospheric CO2 over the last 80 Ma as measured by multiple proxies (stomata leaf pores, 13C in phytoplankton, 13C in paleosols) (data after D. Royer, with permission). Main features: (1) a low-CO2 late Cretaceous (~70-65 Ma) period terminated by the K-T impact, raising CO2 to ~1700-6500 ppm; (2) high-CO2 Eocene (~50-32 Ma) period terminated by a ~35 Ma impact cluster followed by opening of the Drake Passage, formation of the circum-Antarctic cold current and the Antarctic ice sheet, leading to low-CO2 (~200-500 ppm) Oligocene to present climates.

These mass extinction events were superposed on more gradual geological processes, including plate tectonic movements, continental rifting and associated voluminous volcanism, orogenic mountain building events, build up and precipitation of aerosols and the longer term accumulation and sequestration of atmospheric greenhouse gases (Figure 2).

The loss of biodiversity associated with the rise of hominids, and in particular since the onset of the industrial age, constitutes a unique phenomenon in Earth history, fundamentally different in origin although similar in terms of some of its consequences to previous mass extinction events. For the first time in planetary history has a species mastered combustion, first of carbon products of the biosphere, then of fossil carbon products hundreds of millions of years old, magnifying its oxygenating capacities by many orders of magnitude. Thus, whereas human respiration uses about 2 to 7 calories/minute, driving a car commonly uses more than 1000 calories/minute and operating a power plant more than one million calories/minute.

The magnitude of current loss of species is portrayed in figures 3 – 5. According to the Centre for Biological Diversity [4]: "*The human population is 6.8 billion and growing every second. The sheer force of our numbers is dominating the planet to such a degree that geologists are contemplating renaming our era the "Anthropocene": the epoch where the human species is the dominant factor affecting land, air, water, soil, and species. We now absorb 42 percent of the planet's entire terrestrial net primary productivity. We use 50 percent of all fresh water. We've transformed 50 percent of all land. We've changed the chemical composition of the whole biosphere and all the world's seas, bringing on global warming and ocean acidification. Most importantly, we raised the extinction rate from a natural level of one extinction per million species per year up to 30,000 per year. That's three per hour*."

The combustion of the photo-synthetically stored solar energy increases entropy in nature by many orders of magnitude. The mastery of fire by the genus Homo signifies not only a blueprint for the species, but for much of terrestrial nature. The splitting of the atom increases potential release of entropy by 14 to 15 orders of magnitude for a 1 megaton TNT-equivalent device. Only a species capable of controlling the destructive release of such levels of energy would be able to avoid the catastrophic consequences of the release of such levels of energy into the biosphere.

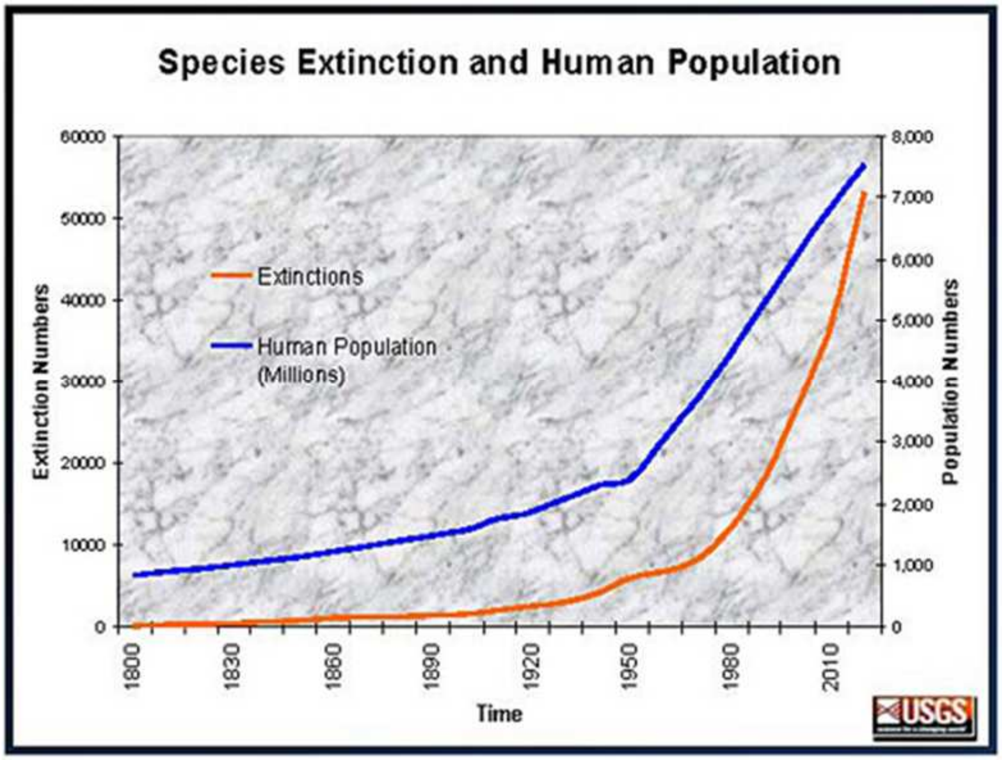

Figure 3

The rise in human population and in the number of extinct species between 1800 and 2010.
http://salsa.democracyinaction.org/o/2167/t/9524/blastContent.jsp?email_blast_KEY=1150373

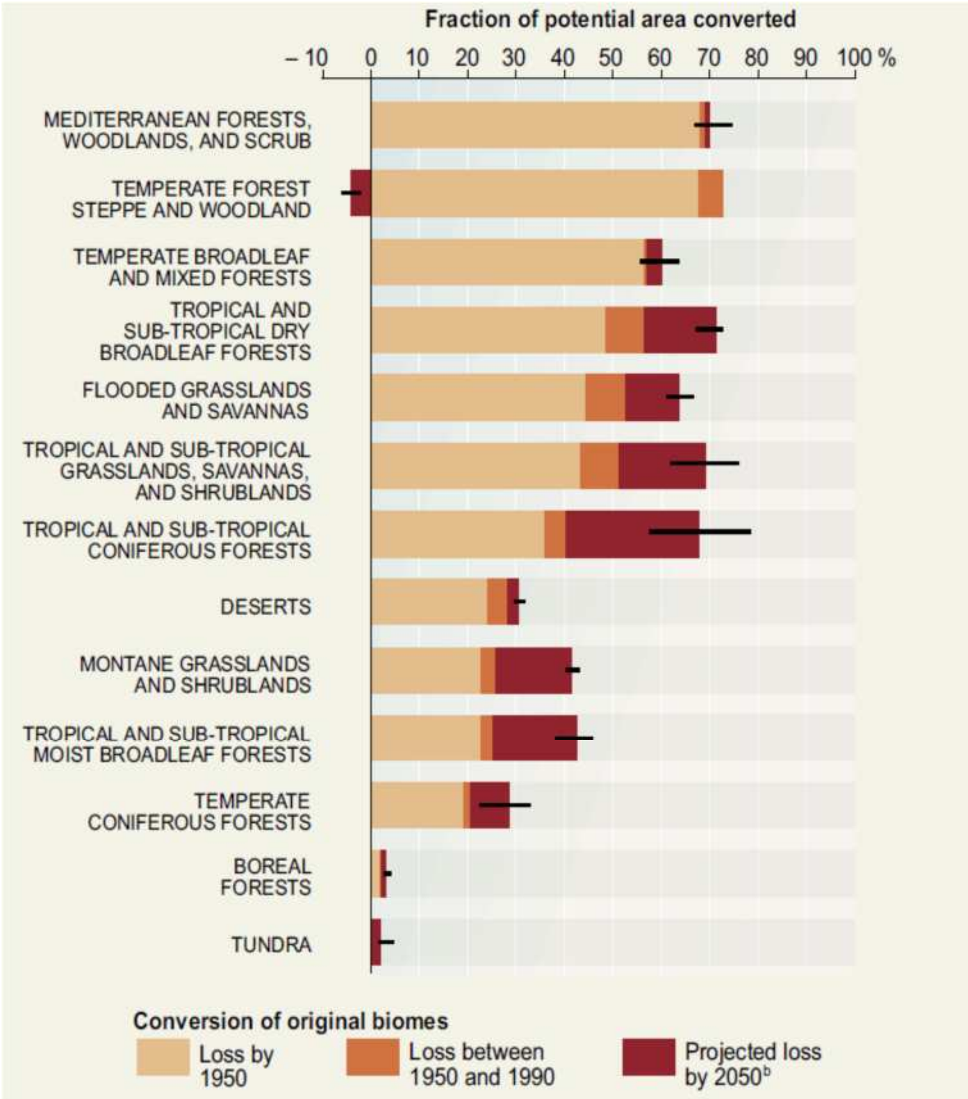

Figure 4. Loss of original biomes (major regional group of distinctive plant and animal communities best adapted to the region's physical natural environment, latitude, elevation, and terrain) by 1950, during 1950 and 1990 and projected loss by 2050.
Ecosystems and Human Well-being Synthesis A Report of the Millennium Ecosystem Assessment
http://www.eoearth.org/article/Ecosystems_and_Human_Well-being:_Biodiversity_Synthesis:_Key_Questions_on_Biodiversity_in_the_Millennium_Ecosystem_Assessment#gen3

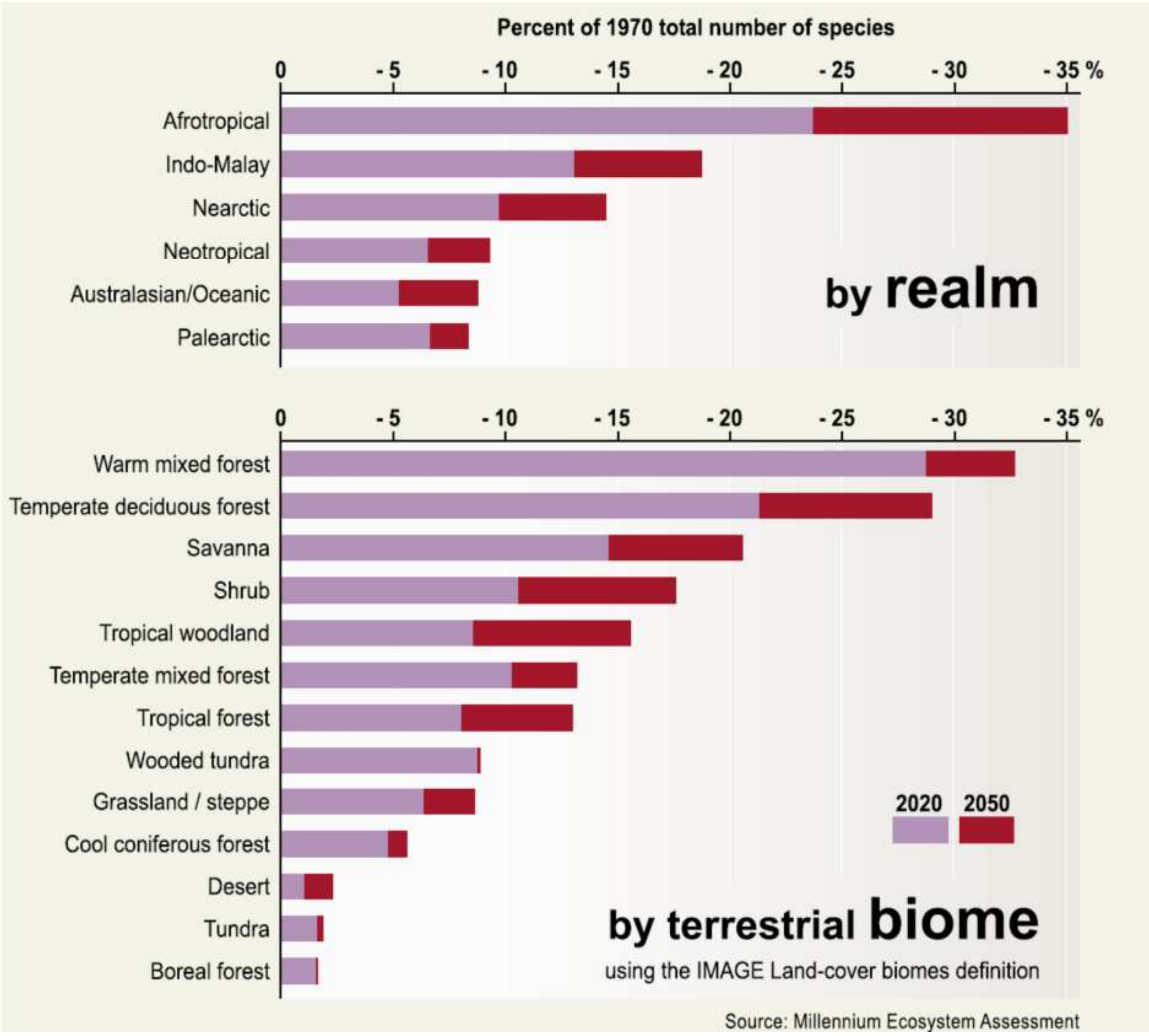

Figure 5. Relative Loss of Biodiversity of Vascular Plants between 1970 and 2050 as a Result of Land Use Change for Different Biomes and Realms in the Order from Strength Scenario.
http://www.maweb.org/en/index.aspx

The rate at which radiative forcing and temperature in the atmosphere are now rising exceeds those of previous events in the atmosphere/ocean system, excepting those associated with mass extinction events. As shown in Figure 6, compared to the mean rise in atmospheric CO2 of +0.43 ppm/year since 1750, with current rises at more than 2 ppm/year, the only recorded CO2 rise of similar magnitude occurred 55 Ma ago, when the release of some ~2000 GtC carbon as methane took place at a rate of ~0.1 ppm/year [5]. In terms of temperatures, the current rise rate of ~0.02 to 0.03 degrees Celsius/year is consistent with the fastest rates recorded in Cainozoic history (Figure 6).

Throughout geological history many species succeeded in adapting to slow to moderate environmental changes and some survived the most extreme environmental events. Burning the world's fossil fuel reserves of more than 2000 GtC [6], analogous to the magnitude estimated for the 55 Ma-old Paleocene-Eocene Thermal event [5], is leading Earth's climate and habitats into uncharted territory.

EVENT	Time interval	MGT change C	MGTemp: C/year	CO2 ppm change	CO2 ppm/year
65 Ma K-T asteroid impact	instantaneous	short term freezing followed by ~ +7.5 C	Freeze/ Fast warming	350 to 2300	Instantaneous
55 Ma Paleocene-Eocene Thermal Maximum	<10,000 years	~ +5 C		700/800 to1800	>0.1 ppm/yr
34-32 Ma End-Eocene	<100,000 years	~ -5 C	0.0005	1300 to 600	0.006 – 0.0013
~25 Ma Late Oligocene thermal high	~ 1x10^6 years	~ +5 C	~0.000005	~300	~0.0003
~16 Ma Mid-Miocene thermal high	~ 2x10^6 years	~ +2 C	~0.000001	~350	~0.00017
~3 Ma late Pliocene thermal high	~400,000	~ +2 C	~0.000005	~200	~0.0005
Glacial terminations	Eemian 10,000	~ +5 C	~0.0005	~100	~0.01
D-O events	~1540 years	~+7 (Greenland)	~0.04		
Interglacial stadials	Youngest dryas: Sharp drop ~1200	- 0.5 C	SHARP DROP (1 – 3 YEARS)	-7	
8.2 event	~100 years	- 3.3 C (regional)	~ -0.033		~0.03
Medieval Warm Period	~400 years	+0.5	~0.00125	+5	~0.0125
Little Ice Age	~60	-0.4	~ -0.006	-5	~0.08
Post-1750	260 years	+0.8 C potential +1.9 C	0.002T /Yr to 0.03T/Yr	+112 ppm	Mean 0.43 ppm/yr up to 2.6 ppm/yr

Figure 6.

Summary of rates of temperature changes, temperature changes per year, CO2 changes and CO2 rates per year during Cainozoic events, showing Anthropocene and current rises in CO2 and tempratures are orders of magnitude higher than those observed in the geological past.

----

[1] http://newscenter.lbl.gov/feature-stories/2010/03/09/alvarez-theory-on-dinosaur/ ; http://books.google.com.au/books?id=kkHhl67ixwEC&pg=PA163&lpg=PA163&dq=Alvarez+impact&source=bl&ots=g5lvd8JNyD&sig=pUUkn01vydFJiJ2a7zVsgavin9g&hl=en&sa=X&ei=EzU7T4mwEszJmAXJ-f3BCw&sqi=2&ved=0CGQQ6AEwCA#v=onepage&q=Alvarez%20impact&f=false ; www.paleolands.org/pdf/DinoextinctN.Am.pdf ; Keller, G., 2005. Impacts, volcanism and mass extinction: random coincidence or cause and effect? Australian Journal of Earth Science, 52/4, 725-757;

[2] Glikson, A.Y., 2005. Asteroid/comet impact clusters, flood basalts and mass extinctions: significance of isotopic age overlaps. Earth and Planetary Science Letters, 236, 933–937; Glikson A.Y., 2009. Mass Extinction of Species: the Role of External Forcing. Journal of Cosmology, Vol 2, pages 230-234.

[3] Ward, P. 2007. Under a Green Sky: Global Warming, the Mass Extinctions of the Past, and What They Can Tell Us about Our Future. http://www.goodreads.com/book/show/630144.Under_a_Green_Sky

[4] http://salsa.democracyinaction.org/o/2167/t/9524/blastContent.jsp?email_blast_KEY=1150373#two

[5] Zachos et al 2008. http://www.nature.com/nature/journal/v451/n7176/full/nature06588.html

[6] http://www.columbia.edu/~jeh1/mailings/2012/20120127_CowardsPart1.pdf

Andrew Glikson

Earth and palaeoclimate science

Australian National University

20-2-2012