How severe is the modern biotic crisis? — A comparison of global change and biotic crisis between Permian-Triassic transition and modern times

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Abstract A comparison of the modern condition with the Permian-Triassic Boundary (PTB) times was made to estimate how severe the modern biotic crisis is. About the global changes, the two periods are correlative in carbon dioxide concentration and carbon isotope negative excursi- on, UV strengthening, temperature increase, ocean acidification, and weathering enhancement. The following tendencies of biotic crises are also correlative: acceleration of extinction rates accompanied by parabolic curve of extinction with a turning interval representing the critical crisis; decline of the three main ecosystems: reefs, tropical rain forests and marine phytoplankton. It is also interesting to note that certain leading organism in both periods undergo accelerated evolution during the crisis. The comparison shows that the modern crisis is about at the turning point from decline to decimation. The extinction curve is now parabolic, and the extinction rate has been accelerated, but the decimation is not yet in real. This is also justified by the modern situation of the three main ecosystems. Modern biotic decline may worsen into decimation and mass extinction but may also get better and recover to ordinary evolution. Since human activities are the main cause of the deterioration of environments and organisms, mankind should be responsible and able to strive for the recovery of the crisis. For the future of mankind, Homo sapiens may become extinct, i.e., disappear without leaving descendants, or evolve into a new and more advanced species, i.e., disappear but leave descendants. For a better future, mankind should be conscious of the facing danger and act as a whole to save biodiversity and harmonize with the environments.

Keywords comparison, global change, biotic crisis, Permian-Triassic Boundary (PTB), modern times

1 Introduction

It is now a general consensus that the modern world is experiencing profound global change and biotic crisis. However, as the debate about the “Climate gate” shows, there are controversies concerning the extent of their severity. One of the basic problem lies in that the modern time is but merely a twinkling of the geologic time. We do not know the whole course of global change and biotic crisis, especially their consequences in the future. In this regard, researches on global changes and synchronous biotic crises in geological history are of important reference value, because they may show the whole process and provide hints on the causes and consequences of the changes and crises. The global changes at Permian-Triassic Boundary (PTB) or Paleozoic-Mesozoic Boundary is one of these events, and the synchronous mass extinction is the most severe and profound one in geological history. A research on the comparison of global changes and biotic crises between PTB and modern times is worthwhile doing. Because both the PTB and modern times belong to critical periods of the geological history with profound global changes and biotic crises, a correlation between the two would be beneficial to both sides. On one hand, the whole course of PTB global change and biotic extinction may serve as a revelation, which will inspire us of the status quo and the future of the earth and its organisms, thus prompt us to adjust the relationship between mankind and nature. On the other hand, the PTB time displays only the results of past global change and biotic extinction in a much more brief record compared with the recent record; it gives a general pattern but leaves a lot of imaginary space for the actual process and causality. In this aspect, researches of modern process and dynamics may provide valuable information by applying the principle of uniformitarianism to the PTB research, which is a hotspot and frontier of geological studies. We are aware that the causes
of the two critical periods are different and that the modern one is mainly due to human activities. However, because the process and initial influences are similar, by comparing with the past, the consequence in the near future would be more predictable so that the mankind may be able to act in advance so as to change the tendency before it becomes inevitable. The past is the key to the present; meanwhile, the present is also the key to the past.

2 Correlation of the global changes between the PTB and modern times

2.1 Carbon dioxide concentration \( [\rho(\text{CO}_2)] \) and negative shift of carbon isotope \( (\delta^{13}\text{C}) \)

As indicated by IPCC, 2007, mainly due to human activities, \( \rho(\text{CO}_2) \) has increased from \( 270 \times 10^{-6} \) to \( 330 \times 10^{-6} \) within past 150 years. The most recent data is 391 \( \times 10^{-6} \) now (April 2010, Mauna Loa CO2 annual mean data from NOAA). Bulk \( \delta^{13}\text{C} \) of the modern oceans oscillated by glacial-interglacial changes and did not show remarkable long-term negative shift. However, a multi-parameter mixing approach (MIX) to reconstruct the industrial-era (1765–1992) change in \( \delta^{13}\text{C} \) of dissolved inorganic carbon revealed that the industrial-era near-surface \( (\lesssim 200 \text{ m}) \) \( \delta^{13}\text{C} \) change ranged from \(-0.8\% \) in the subtropics to \(-0.4\% \) to \(-0.2\% \) north of 40°N (Sonnerup et al., 2007), so a negative shift of marine \( \delta^{13}\text{C} \) seems existing at 10^6/a scope. Negative shifts of \( \delta^{13}\text{C} \), sometimes quite strong, also occur in recent terrestrial deposits (Xie et al., 2004a, b).

The same tendency happened during PTB time. Based on the known relationship between leaf stomatal abundance and growing-season CO2 concentrations, Retallack (2002) measured the stomatal index of mid-Permian to late Triassic Lepidopteris and concluded that the Early Triassic \( \rho(\text{CO}_2) \) was \( 3314 \times 10^{-6} \pm 1097 \times 10^{-6} \), nearly 10 times that of today, and 2 times the averaged Permian level. It should be noted however that, although the Early Triassic \( \rho(\text{CO}_2) \) is much higher than modern time, its growth rate during PTB interval is only \(<0.01 \times 10^{-6} \) annually, whereas the growth rate of modern \( \rho(\text{CO}_2) \) would be from \( 0.4 \times 10^{-6} \) to \( 2 \times 10^{-6} \) annually^1.1.

The negative shift of \( \delta^{13}\text{C}_{\text{carb}} \) during PTB time is recognized worldwide. After a relatively stable period in Changhsingian, all latest Changhsingian curves show an increasingly rapid decrease in values, becoming negative just below the PTB (Yin et al., 2007). The scope of the negative shift ranged from \(-0.65\% \) (Xie et al., 2007) to \(-1.62\% \) (Jin et al., 2000) at the Meishan GSSP section. Scope of stronger negative excursion may reach \(-5\% \), e.g., in Shahreza, Iran (Korte et al., 2004). This ubiquitous feature is important because it marks the beginning of a profound global change just prior to the PTB.

2.2 Global warming

There is a discernible warming trend of the global surface temperature over the past 150 years (1950–2007), from around \(-0.3^\circ\text{C} \) to \(+0.5^\circ\text{C} \) (IPCC, 2007). It may be too rigid to attribute most, if not all, of the historical global warming to \( \rho(\text{CO}_2) \) concentration, because there are arguments that since available ice core data indicate the temperature always lead the CO2 changes, CO2 could not be the driver. The most recent 150 a climate changes may be caused partially by CO2 and partially by natural fluctuations.

Palaeotemperature increase from Latest Permian to Early Triassic has been reported from oxygen isotopic values \( (\delta^{18}\text{O}) \) of marine biogenic carbonate (Veizer et al., 2000). From Latest Permian to Earliest Triassic, the \( \delta^{18}\text{O} \) shifted from \(+0.5 \) to \(-1.5\% \), corresponding to \( 8^\circ\text{C} \) of temperature rise. The warming trend was also echoed by estimation from the stomatal index \( (\text{SI})^2 \) of fossil leaves of Lepidopteris. According to SI, atmospheric CO2 concentration reached maxima in the latest Permian and then decreased to a negative shift in Early Triassic (Retallack, 2001, 2002), which reflects a strong warming tendency in accordance with the \( \delta^{18}\text{O} \) shift.

2.3 Ultraviolet (UV) radiation

UV with wavelength between 290–325 nm is the main part of UV that may damage the immune system of organisms, causing skin cancer and other diseases. The ozone layer absorbs most UV with wavelength below 300 nm and protects organisms from over-exposure to UV. However, ozone depletion, the Antarctic ozone hole and a decline of ozone layer since the late 1970s probably due to overuse of chlorofluorocarbons (CFCs), has increased the modern UV exposure (Alpen, 1998).

Based on mutagenesis of PTB palynomorphs, Visscher et al. (2004) suggested that excessive UV radiation may have caused the PTB biotic crisis, especially the land vegetation, and meanwhile accelerated the genesis of new lineages. The extensive volcanism during that interval produced enormous SO2 and formed large volume of

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1) The PTB \( \rho(\text{CO}_2) \) growth rate. The \( \rho(\text{CO}_2) \) difference during PTB is about 1500–2000 ppm according to figures in Retallack (2001, 2002); the updated duration of PTB strata is ca. 300 ka according to pers. comm. of Sam Bowling 2009, 11. The modern \( \rho(\text{CO}_2) \) growth rate: \( 0.4 \times 10^{-6}/a \) is calculated from \( (330–270) \times 10^{-6}/150a; 2 \times 10^{-6}/a \) is from data of 2009 for Mauna Loa, Hawaii, NOAA)

2) \( \text{SI} \) (stomatal index) = \( 100 \times N_s / (N_s + N_e) \), where \( N_s \) is the number of stomates, and \( N_e \) is the number of epidermal cells in the same area of cuticle. There is an inverse relationship between atmospheric CO2 concentration and stomatal density, so SI may serve as a palaeobarometer of atmospheric CO2 during growth of fossil plant leaves.