Oxygen Escape Linked to Geomagnetic Reversals and Mass Extinctions

In the past half century, many efforts have been devoted to understanding the links between geomagnetic reversals and mass extinctions, but no consensus has been reached. A recent research by geophysicists at the Institute of Geology and Geophysics, Chinese Academy of Sciences revealed that enhanced oxygen escape, which might have triggered a continual environmental degradation occurring over the long-lasting span of extinctions, could be an important link in the causal chain between geomagnetic reversals and mass extinctions, as a result from their analysis of the latest datasets and a simulation of oxygen ion escape rate during the Triassic–Jurassic event.

Based on their analysis of the newest databases available for the Phanerozoic era, the IGG scientists found that when the marine diversity showed a gradual pattern of mass extinctions lasting millions of years, the reversal rate increased and the atmospheric oxygen level decreased (Figure 1). These features provide some new clues to hypothesize the causal mechanisms of mass extinctions. To establish a successful hypothesis, however, strict tests are needed to see if it could explain the patterns of mass extinctions. The fossil records reveal that a mass extinction has a gradual pattern persisting for millions of years, during which a stepwise pattern manifested itself comprised of a series of impulse extinctions. The combination of patterns suggests that the main cause should be continual environmental degradation. It has been verified that the drop of atmospheric O_2 level could be able to induce environmental degradation, because reduced supply of O_2 is lethal for most species. However, it is difficult to explain the O_2 level drops if only considering Earth-bounded geochemical processes. A possible scenario could be that in wake of a reversal, the O_2 molecules, exposed to cosmic radiation and interplanetary weathers under an extremely weakened magnetic field, were broken into oxygen atoms by solar radiation and subsequently ionized. These O^+ ions were further energized in the ionosphere by the solar wind forcing and could have thus overcome the containment by the magnetosphere and gravity, hence could have escaped into the interplanetary space.

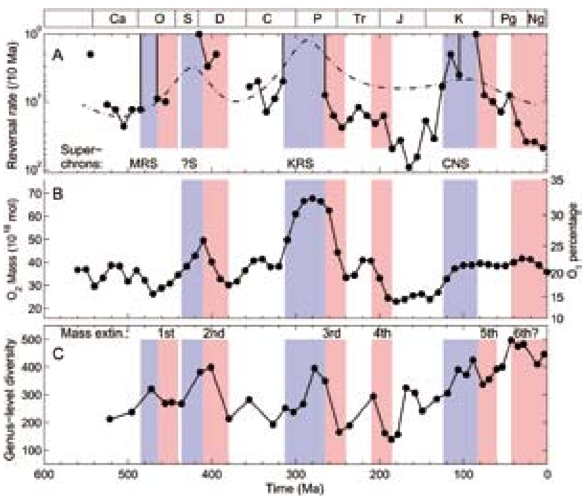

Figure 1: Temporal evolution of reversal rate, O_2 level and marine diversity over the Phanerozoic era.

Prof. WEI Yong with his co-workers hypothesizes that geomagnetic reversals have caused the O_2 level drops and the subsequent mass extinctions, since the magnetospheric containment of oxygen is expected to have been severely weakened when the dipole collapses during geomagnetic reversals. They speculated that accumulated oxygen escape during an interval of increased reversal rate could have led to the catastrophic drop of oxygen level, which is known to be a cause of mass extinctions. To test this new

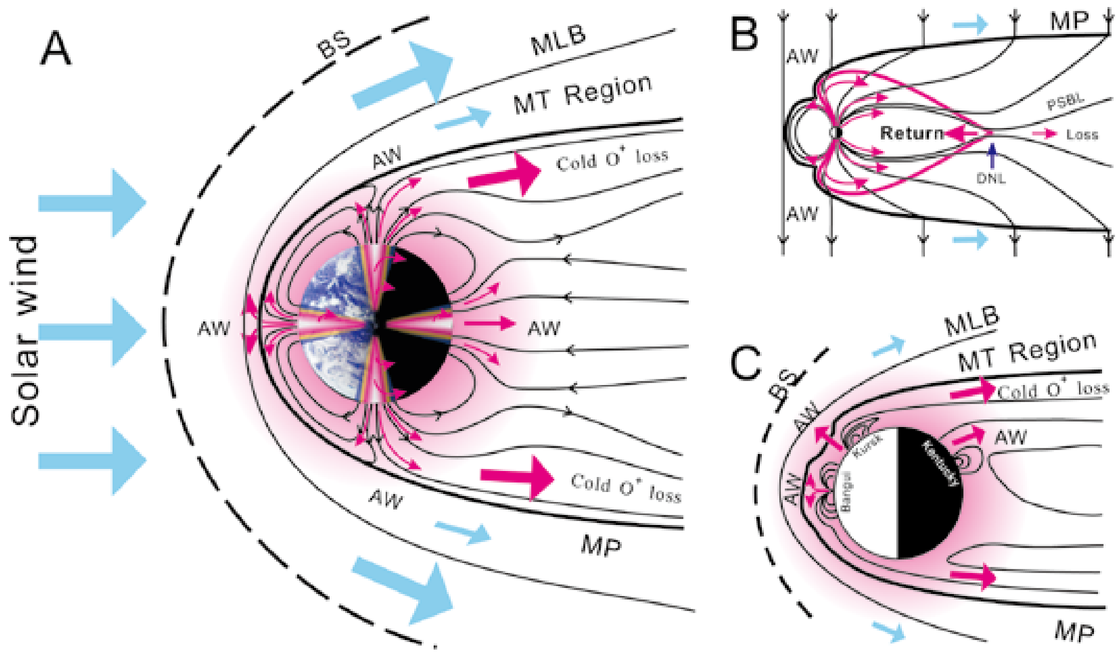

Figure 2: Ion escape scenarios for the reversing field, present field and no field of Earth. (A) Mars-like ion escape in a quadrupole-dominated magnetosphere for reversing field. (B) Earth-like ion escape for present field. (C) Fully Mars-like ion escape when the geodynamo totally stops.

hypothesis, they simulated the oxygen ion escape rate for the Triassic–Jurassic event, using a modified Martian ion escape model (Figure 2) with an input of quiet solar wind inferred from Sun-like stars. The results indicate that a geomagnetic reversal could have enhanced oxygen escape rate by 3–4 orders of magnitude if the magnetic field was extremely weak, even without consideration of space weather effects. This suggests that the hypothesis could be a possible explanation of the newest data. Therefore, if the causal relation between geomagnetic reversal and mass extinction indeed exists, it should be a "many-to-one" scenario rather the previously thought "one-to-one", and planetary magnetic fields could be much more important than previously thought for planetary habitability.

For more information please refer to:

Wei *et al*. Oxygen escape from the Earth during geomagnetic reversals: implications to mass extinction. *Earth and Planetary Science Letters*, 2014, 394: 94–98.