Permian–Triassic Climatic and Environmental Extremes and Biotic Response (IGCP 630: 2014–2018): Goals and Achievements

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IGCP 630 and its structures

IGCP 630, with its full title: Permian–Triassic (P–Tr) climatic and environmental extremes and biotic response, is an International Geoscience Program project sponsored by the United Nation Educational, Scientific & Cultural Organization (UNESCO) and International Union of Geological Sciences (IUGS). This project was approved in 2014 and ended in 2018, and it has applied for one-year extension in 2019. IGCP 630 consists of 150 geoscientists across multidisciplinary geosciences from 27 countries around the world. Its co-leader team is chaired by Prof. Zhong-Qiang Chen from China University of Geosciences (Wuhan), China and also include other 13 world-leading geoscientists in the studies on the global P–Tr events: Thomas J. Algeo (USA), Margret L. Fraiser (USA), Steve Kershaw (UK), Jinnan Tong (China), Sylvie Crasquin (France), Michael J. Benton (UK), Guang R. Shi (Australia), Charles M. Henderson (Canada), Arnie Winguth (USA), Paul B. Wignall (UK), Kunio Kaiho (Japan), Ghulam Bhat (India), and Yuri D. Zakharov (Russia). Its logo is as below (Fig. 1). On its web-page [http://igcp630.cug.edu.cn] you can find general information about the project aims, co-leaders, project members, recent announcements, and photos from conferences and field excursions.

IGCP 630:
Permian-Triassic climatic & environmental extremes and biotic response

Fig. 1. The logo of IGCP 630: Permian–Triassic climatic and environmental extremes and biotic response.

Background

Many marine ecosystems are under threat at the present day. The geological record provides numerous analogues of environmental upheavals and major biocrises, the most disruptive of which occurred during the P–Tr transition at ~252 million years ago. Many of the factors that contributed to the P–Tr biotic crisis, e.g., increased atmospheric CO_2 concentrations, rapid global warming, oceanic anoxia, and hypercapnia (CO_2

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poisoning) are also observed in the present day or are anticipated to develop in the near future. The P–Tr transition may thus record a natural experiment in global-scale ecosystem collapse that, if properly deciphered, could provide important insights into possible responses of modern marine ecosystems to present day climate and environmental change. This project will address themes related to current global concerns and issues including the response of the biosphere to global warming, sustenance of global biodiversity, and maintaining the habitability of planet Earth.

This large international collaboration project aims to investigate the climatic and environmental extremes and ecosystem’s response during the P–Tr mass extinction and its aftermath through analyses of the rock and fossil records of South China, Tibet, Japan, India, elsewhere in Asia, eastern Europe, Russia, Canada, Greenland, Spitsbergen, western US, western Australia, and New Zealand. Through detailed studies of latest Permian to Early Triassic biostratigraphy, paleontology, paleoecology, sedimentology, geochemistry, and biogeochemistry in the above regions, this project will attempt to document global ecosystem’s collapse and rebuilding in seas and on land, formulate the mechanism biotic response to climatic and environmental extremes at fossil group and ecosystem levels; to reconstruct the global latest Permian to Early Triassic oceanic and climatic conditions and probe mutual effect mechanism between extreme environment and high temperature; and to correlate all of this data in a global stratigraphic framework. Ultimately, this project attempts to (1) reveal climatic and environmental extremes at a global scale and their impacts on ecosystems in seas and on land, (2) elucidate the factors controlling biotic recovery in various habitats and climate zones, (3) determine the similarities and differences in the responses of different marine groups to biotic crisis, and (4) assess the effects of climate or other geological events on the restoration of the defaunated marine ecosystems.

These goals will be achieved primarily by collaborative fieldwork in key uppermost Permian to Middle Triassic successions in >10 different countries over five years and related laboratory work in over 20 different countries. The results of IGCP 630 advance scientific understanding of the interactions between the biosphere and geosphere and lead to a better understanding of ancient defaunation events. The firm support and active involvement in this project of most top scientists in this field from around the world will lead to unique training opportunities for postgraduate students from a range of countries (Argentina, Austria, Australia, Canada, China, India, Japan, France, Germany, Iran, Russia, Switzerland, Thailand, UK, USA) as well as professionals from developing and developed regions alike. As a result, the proposed project will provide a friendly platform for participants to communicate their own research results and also bring together global experts, and research facilities to solve a truly global-scale problem. The competitive track records of the proposers underscore this project’s high chance of academic success as well as its potential to achieve significant societal benefits in the form of knowledge sharing and enhanced scientific cooperation between nations.

Ultimate goals

The ultimate goal of IGCP 630 is to provide better understanding of climatic and environmental extremes and their mutual effect mechanism as well as biotic response to those events over the P–Tr transition. Hopefully, the outcomes of IGCP 630 provide some lessons helping manage the present-day defaunation events and subsequent recovery of marine ecosystems. Specifically we aim to:

- utilize stratigraphically important fossil groups (e.g. conodonts, ammonoids, microflora so on) to establish robust biostratigraphic frameworks for the marine and non-marine P–Tr successions worldwide;
- utilize integrated stratigraphic approaches (biostratigraphy, cyclostratigraphy, and chronology) to correlate marine successions with terrestrial strata, to enable accurate, high-resolution global correlation;
- utilize paleoecologic, paleontological (body and trace fossils), and sedimentologic information to fully document marine communities or non-marine assemblages throughout the recovery interval in a variety of environments from deep sea to continental habitats and tropical to temperate climate zones, and summarize ecosystem’s collapse and rebuilding patterns in seas and on land;
- utilize geochemical signatures (carbon, oxygen and sulfur isotopes, and biomarkers) as independent indicators to reveal environmental and climatic extremes during the recovery stages in different habitats and

latitude zones;

- reveal catastrophic events recorded in the P–Tr transition and elucidate their relationships with those triggering the P–Tr mass extinction as well as effects on the Early Triassic ecosystems by integrating geochemical, paleontological and sedimentological data;
- model extreme climatic and environmental change trends and biotic responses over P–Tr transition at different scales, explore the affect mechanism between extreme climate and devastated oceanographic conditions, elucidate the factors controlling ecosystem's collapse and building in a global scale, and, hopefully, provide some lessons for management of modern-day degraded ecosystems.

To achieve the above six aims, we undertake the following detailed studies:

1) Biostratigraphic control. Based on previously published data, results from the recently completed IGCP 572 (2008–2013: led by ZQ Chen), and our further stratigraphic works, we will attempt to establish robust global Early-Middle Triassic biostratigraphic frameworks of marine and terrestrial successions, which provide a useful and sound base for studying environmental and climatic extremes and biotic response.

2) Integrated stratigraphic correlations between marine and terrestrial P-Tr successions. This study provides an update stratigraphic correlation between the marine and terrestrial P-Tr and Early Triassic successions by integrating high-resolution biostratigraphic, cyclostratigraphic, magnetostratigraphic, and radiometric age data. The high-resolution stratigraphic correlations of marine and non-marine successions provide precise time-framework for evaluating the impact of environmental and climatic extremes on ecosystems in seas and on land.

3) Ecosystem's collapse and rebuilding in seas and on land. Latest Permian to Early Triassic paleoecologic, paleontological (body and trace fossils), and sedimentologic information will be fully documented to reconstruct community structures from the targeted regions. Biosedimentary structures including microbialites, MISSs, and sea-floor fans are also documented or summarized. We will test this hypothesis that microbialites may have provided the basic food chains for restructuring of ecosystem in the Early Triassic. The relationships between microbialites and metazoans within the microbialite-dominated community and between microbialite and metazoan communities will be determined. Community structural changes throughout the recovery interval in a variety of environments from deep sea to continental habitats and tropical to temperate climate zones will be assessed to develop ecosystem's collapse and rebuilding patterns in seas and on land.

4) Isotopic geochemistry and biomarker studies. Recent studies show that the positive-negative shifting cycles of carbon isotope excursions may indicate that large perturbations of the carbon cycle, reflecting environmental extremes. Oxygen isotopes from conodont bio-apatite revealed that a rapid increase in seawater temperature occurred in association with the P–Tr mass extinction and that lethally hot temperature conditions prevailed in Early Triassic oceans. The analysis of biomarkers has recently applied to detect anoxic seawater conditions. These methods are also applied to this project and an electronic global database of geochemical and biomarker analysis data of the P–Tr interval will be constructed during the life course of the project.

5) Comprehensive analysis environmental and climatic extremes and their impacts on ecosystems in seas and on land. By integrating geochemical, paleontological and sedimentological data from both marine and terrestrial successions in different habitats and climate zones, we reveal catastrophic events recorded in the P–Tr transition and elucidate their relationships with those triggering biotic extinction and effects on the Early Triassic ecosystems.

6) Modelling extreme climatic and environmental change traits and ecosystem's responses through the P–Tr transition. A supercomputing modelling is applied in this project to predict extreme climatic and environmental change trends and biotic responses over P–Tr transition at different scales. The modelling will explore the affect mechanism between extreme climate and devastated oceanographic conditions, elucidate the factors controlling ecosystem's collapse and building in a global scale, and, hopefully, provide some lessons for management of modern-day degraded ecosystems.

Concluding remarks and achievements

In the past five years (2014–2018), IGCP 630 project members were very productive, and published averagely 120–150 papers in SCI-cited journals per year. IGCP 630 project has also organized eight important thematic issues to publish the updated research results by projects members (Appendix 1).

Briefly, IGCP 630 has achieved in following 11 aspects:

(1) Early–Middle Triassic biostratigraphy: More precise and comprehensive bio-chronological frameworks were established for the marine and terrestrial Lower and Middle Triassic successions in several major regions: China, India, Pakistan, Madagascar, South Africa, Armenia, Russia, and Spitsbergen;

(2) Extinction and recovery of several major fossil groups: P–Tr diversity dynamics of several clades such as radiolarians, conodonts, ostracods, brachiopods, and sponges have been re-studied in details. The evolutionary dynamics of these clades are different from one another.

(3) Both extreme hot seawater temperature and widespread anoxia were suggested to be major killers for the P–Tr crisis and have delayed biotic recovery in Early Triassic;

(4) Microbial proliferation following the P–Tr crisis was supported by giant ooids in addition to both microbialites and microbial mats;

(5) Marine and terrestrial acidifications may have accounted for biotic crises in ocean and on land;

(6) The Early and Middle Triassic astronomical cyclo-chronologic frameworks are established and update the newest Geological Time Scale (2016);

(7) Global and local oceanic anoxia are unraveled, using U isotopes and other proxies, through the P–Tr transition, suggesting that anoxia may have caused biotic extinction and delayed post-extinction recovery;

(8) Early Triassic hothouse regimes may have been controlled by obliquity-forced cycles (1.2 myr), while local/regional anoxia were controlled by ~100 kyr eccentricity.

(9) Precisely calibrated Sill eruptions of Siberian trap using radiometric ages, which are coeval with the P–Tr extinction; Hg concentration anomaly and isotopic excursions also indicate volatile eruption of the Siberian trap coinciding with the P–Tr extinction, suggesting a cause-result relationship between the two.

(10) Ecologic analysis of global fossil records reveals that animals having nektonic lifestyle recovered earlier in late Early Triassic, implying a faster recovery than previously thought.

(11) A number of unexpected diverse metazoans and ichnofaunas were found in the immediate aftermath of the P–Tr extinction, suggesting that some local refugia or habitable zones existed after the P–Tr crisis.

Key words: IGCP project, Permian-Triassic, mass extinction, biotic recovery, volcanism

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Appendix 1. Major thematic issues organized by IGCP 630 since 2014

Guest Editor	Year	Special Issue Title	Journal	Volume	Reference
Chen, Z.Q., Algeo, T.J., Bottjer, D.J.	2014	Global Review on Permian–Triassic Mass Extinction and Subsequent Recovery, Part I	*Earth-Science Reviews*	137	Chen et al., 2014a
Chen, Z.Q., Joachimski, M., Montanez, I., Isbell, J.	2014	Deep Time Climatic and Environmental Extremes and Ecosystem Response	*Gondwana Research*	25	Chen et al., 2014b
Chen, Z.Q., Algeo, T.J., Bottjer, D.J.	2015	Global Review on Permian–Triassic Mass Extinction and Subsequent Recovery, Part II	*Earth-Science Reviews*	149	Algeo et al., 2015
Chen, Z.Q., Zhou, C.M., Stanley, G.J.	2017	Biosedimentary records of China from the Precambrian to present	*Palaeogeography, Palaeoclimatology, Palaeoecology*	474	Chen et al., 2017a
Chen, Z.Q., Algeo, T.J., Sun, Y.D., Schoepfer, S.D.	2017	The Palaeozoic–Mesozoic Transition in South China: Oceanic Environments and Life from Late Permian to Late Triassic 1	*Palaeogeography, Palaeoclimatology, Palaeoecology*	486	Chen et al., 2017b
Chen, Z.Q., Luo, M.	2018	Permian and Triassic World	*Journal of Earth Sciences*	29	Chen et al., 2018
Chen, Z.Q., Algeo, T.J., Schoepfer, S.D.	2019	The Palaeozoic–Mesozoic Transition in South China: Oceanic Environments and Life from Late Permian to Late Triassic 2	*Palaeogeography, Palaeoclimatology, Palaeoecology*	519	Chen et al., 2019a
Chen, Z.Q., Hu, X.M., Montanez, I., Ogg, J.G.	2019	Sedimentology as a Key to Understanding Earth and Life Processes	*Earth-Science Reviews*	189	Chen et al., 2019b