Recovery of lacustrine ecosystems after the end-Permian mass extinction

With the support by the National Natural Science Foundation of China and the Chinese Academy of Sciences, the research team led by Prof. Wang Bo (王博) at the State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, uncovered the recovery of lacustrine ecosystems after the end-Permian mass extinction, which was published in *Geology* (2020, 48: G47502.1).

The end-Permian mass extinction (EPME), approximately 252 million years ago (Ma), was the greatest biological and ecological crisis of the Phanerozoic Eon on Earth. Marine ecosystems are thought to have recovered substantially by the middle to late Anisian (about 8—10 million years later) and their restoration was still ongoing in the latter part of the Late Triassic (200 Ma). However, the pattern of recovery of lacustrine ecosystems is still unclear due to the highly fragmentary freshwater fossil record.

Prof. Wang's team conducted a systematic study of the Middle Triassic lacustrine sediments in the Ordos Basin of China, including stratigraphy, sedimentology, and palaeontology in three outcrops on the southern edge of the basin. They found that both lake and peat-forming forest ecosystems probably took as long as 10 million years to recover after EPME.

U-Pb isotopic ages of tuffaceous layers in three outcrops dated the Triassic organic-rich shale to 242 Ma in the Middle Triassic Tongchuan Formation. The organic-rich shale in the lower part of the Tongchuan Formation represents the first known appearance of a deep perennial lake after the EPME and is 5 million years earlier than any previous record.

The shales have yielded abundant fossils, including microalgae, macroalgae, notostracans, ostracods, insects, fishes, and fish coprolites. They provide data on the earliest known Triassic complex lacustrine ecosystem. Such an ecosystem is a key component of Mesozoic lakes, which were different from pre-Mesozoic lakes in which dipteran larvae were absent and aquatic beetles were rare. The restoration of a complex lacustrine ecosystem was coincident with the termination of the "coal gap," which was an interval of approximately 10 million years when no coals were deposited worldwide. It is generally believed that the reoccurrence of the Middle Triassic coal seam represents a significant restoration of the forest ecosystem after the EPME. Therefore, both lake and peat-forming forest ecosystems probably took up to 10 million years to recover, much longer than the period of recovery of plant communities inferred from palynological data.

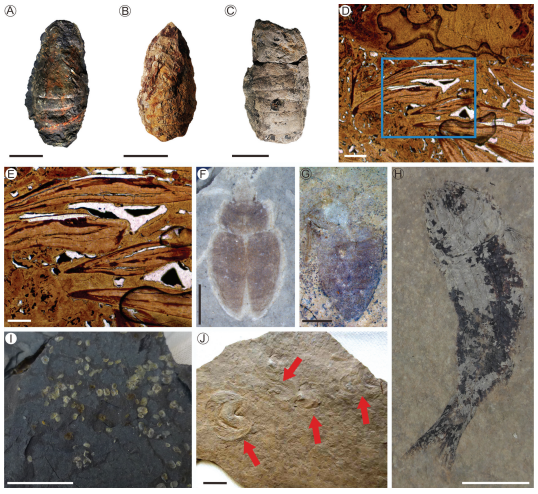

Figure Representative fossils from the organic-rich shale and mudstone of the Tongchuan Formation. A—C: fish coprolites; D and E: sliced photomicrographs of fish coprolite; F and G: beetles; H: fish; I: ostracods; J: tadpole shrimps.

The hot Early Triassic climate would have limited dissolved oxygen in lakes, potentially hindering ecosystem recovery. A subsequent major increase in marine carbon burial in the Anisian could, however, has caused CO_2 drawdown and global cooling, improving lacustrine conditions. In addition, the abundant volcanic ash likely transferred nutrients into the water and probably significantly increased the efficiency of primary productivity in the Ordos Basin. Therefore, both the climatic cooling and high volcanic nutrient input most likely facilitated development of this complex lake community.