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DISCUSSION

Discussion of 'The Triassic U–Pb age for the aquatic long-necked protorosaur of Guizhou, China'

Keywords: Panxian, reptile, extinction, recovery.

J. Liu comments: First, I would like to congratulate Wang *et al.* (2014) for their important work on the dating of the Panxian fauna, a Triassic fossil Lagerstätte that has produced many exquisitely preserved marine reptiles (Motani *et al.* 2008) and that marks the full recovery of the marine ecosystem (Jiang *et al.* 2009) following the Permian–Triassic marine mass extinction (PTME). Papers by Wang *et al.* (2014) and alike are especially welcomed by vertebrate palaeontologists since they provide precise dating results for some of the most important vertebrate fossils in the world, such as the bizarre protorosaur *Dinocephalosaurus orientalis* (Li, Rieppel & LaBarbera, 2004) and the earliest marine archosaur *Qianosuchus mixtus* (Li *et al.* 2006). This related topic is also interesting because of the very recent debate about the timing of recovery from the PTME, the largest biodiversity crash during the Phanerozoic, from the predators' perspective (Chen & Benton, 2012; Scheyer *et al.* 2014).

There are several fossil Lagerstätten recently discovered in China that have generated numerous beautifully preserved Triassic marine reptiles (Benton *et al.* 2013). The Middle Triassic Panxian fauna (Motani *et al.* 2008; Jiang *et al.* 2009) is one of them. Together with the time-equivalent Luoping biota (Hu *et al.* 2011), they mark the full recovery of marine ecosystems from the PTME by the Anisian (Chen & Benton, 2012; Benton *et al.* 2013). However, the absolute dating of these fossil Lagerstätten was previously absent. Wang *et al.* (2014) provided the first of such dating, improving our understanding of the timing of recovery from the PTME. However, one of the major conclusions of Wang *et al.* (2014) is that the reported age is 14 Ma older than the previous estimation based on the conodont study. It is this conclusion that will lead to some confusion among vertebrate palaeontologists.

When Li, Rieppel & LaBarbera (2004) published their report about a new *Dinocephalosaurus* specimen, there was no conodont study available for the age of the strata generating *Dinocephalosaurus* and the associated Panxian fauna. Instead, Li, Rieppel & LaBarbera (2004) only generally pointed out that the specimen comes from the Anisian Guanling Formation. At the time they published their paper, the most updated geological time scale (GTS) available would have been the one by Palmer & Geissman (1999). The Anisian stage ranged from 242 Ma to 234 Ma in this edition of the GTS, so it remains unclear why Li, Rieppel & LaBarbera (2004) said that the new *Dinocephalosaurus* specimen dates to 230 Ma. Later on, Sun *et al.* (2006) performed a detailed conodont study related to the Panxian fauna, and the paper clearly concluded that the age of the Panxian fauna is early Pelsonian based on the recognition of the *Nicoraella kockeli* condont zone. The current work on the Triassic geological time scale places the Pelsonian substage between about 244 and 245 Ma (Gradstein *et al.* 2012). Thus, the radiometric dating by Wang *et al.* (2014) provides a perfect match to the result of the conodont study (Sun *et al.* 2006), and in fact there is no 14 Ma difference between the new age and what was expected. All information, biostratigraphic and radiometric, agrees.

Wang *et al.*'s (2014) result also has important implications for the timing of biotic recovery from the PTME. In the Triassic ocean, marine reptiles were the major large predators, the role of which is occupied by the marine mammals in the modern ocean (Massare, 1987). After comparing them with the living marine mammals, Massare (1987) divided Mesozoic marine reptiles into seven more or less overlapping ecological guilds. The type with two cutting edges on their teeth, the cutting guild, was accepted as the apex predators in the relevant ecosystems (Massare, 1987). In the Panxian fauna, *Qianosuchus mixtus* is such a large apex predator retaining dagger-like teeth (Li *et al.* 2006). It is interesting to note that the only other Triassic macropredatory tetrapod, the ichthyosaur *Thalattoarchon saurophagis*, was also reported from the strata with an absolute age of 244–245 Ma (Fröbisch *et al.* 2013). Since such large marine apex predators appeared simultaneously in both the Tethyan and Panthalassic oceans (Fig. 1) at 244–245 Ma when oceanic anoxia had just ended and key life modes such as coral reefs were just being re-established in the sea (Chen & Benton, 2012), it seems that healthy and stable marine ecosystems had not been established globally until Middle Triassic time, unless the future discovery of such macropredatory predators in the Lower Triassic strata falsifies this hypothesis.

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References

BENTON, M. J., ZHANG, Q., HU, S., CHEN, Z.-Q., WEN, W., LIU, J., HUANG, J., ZHOU, C., XIE, T., TONG, J. & CHOO, B. 2013. Exceptional vertebrate biotas from the Triassic of China, and the expansion of marine ecosystems after the Permo-Triassic mass extinction. *Earth-Science Reviews* **125**, 199–243.

CHEN, Z.-Q. & BENTON, M. J. 2012. The timing and pattern of biotic recovery following the end-Permian mass extinction. *Nature Geoscience* **5**, 375–83.

FRÖBISCH, N. B., FRÖBISCH, J., SANDER, P. M., SCHMITZ, L. & RIEPPEL, O. 2013. Macropredatory ichthyosaur from the Middle Triassic and the origin of modern trophic networks. *Proceedings of the National Academy of Sciences of the United States of America* **110**, 1393–7.

GRADSTEIN, F. M., OGG, J. G., SCHMITZ, M. & OGG, G. 2012. *The Geologic Time Scale 2012*. Elsevier.

HU, S. X., ZHANG, Q. Y., CHEN, Z. Q., ZHOU, C. Y., LV, T., XIE, T., WEN, W., HUANG, J. Y. & BENTON, M. J. 2011. The Luoping biota: exceptional preservation, and

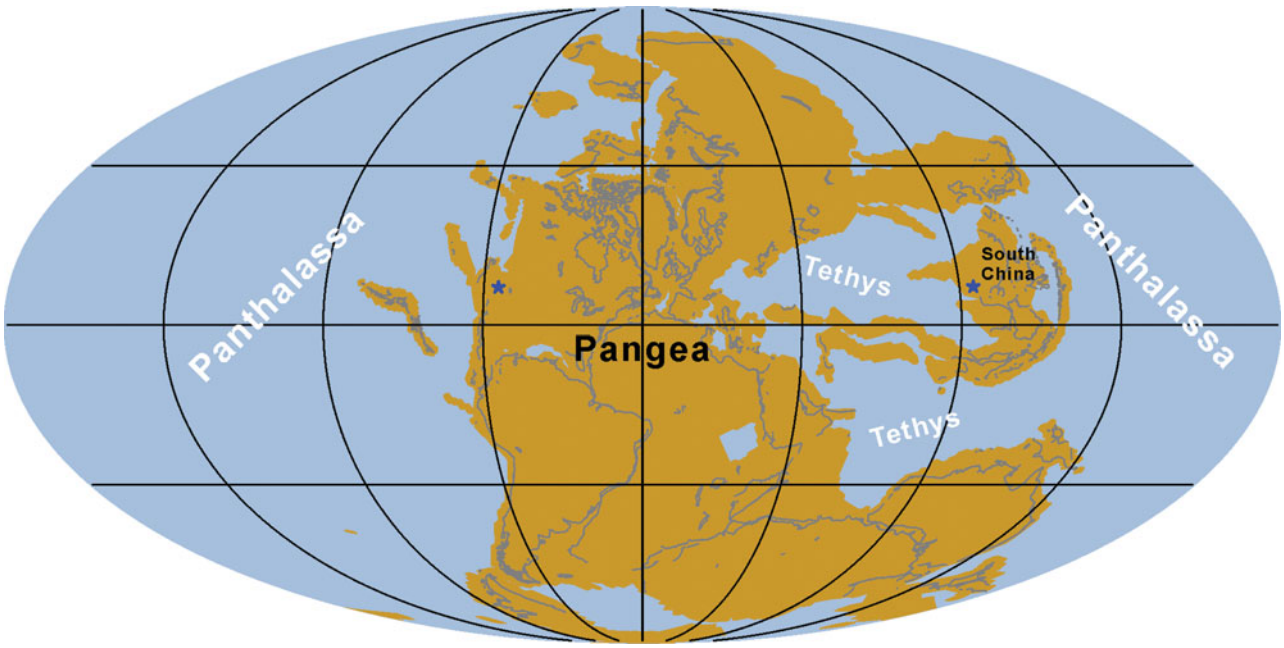

Figure 1. (Colour online) Palaeogeographic reconstruction showing the global distribution of Anisian macropredatory tetrapods in the sea (marked with the pentagram; the base is a 245 Ma map generated using the plotting software designed by John Alroy, available free at http://fossilworks.org/).

new evidence on the Triassic recovery from end-Permian mass extinction. *Proceedings of the Royal Society B: Biological Sciences* 278, 2274–82.

JIANG, D. Y., MOTANI, R., HAO, W. C., RIEPPEL, O., SUN, Y. L., TINTORI, A., SUN, Z. Y. & SCHMITZ, L. 2009. Biodiversity and sequence of the Middle Triassic Panxian marine reptile fauna, Guizhou Province, China. *Acta Geologica Sinica* **83**, 451–9.

LI, C., RIEPPEL, O. & LABARBERA, M. C. 2004. A Triassic aquatic protorosaur with an extremely long neck. *Science* **305**, 1931.

LI, C., WU, X. C., CHENG, Y. N., SATO, T. & WANG, L. T. 2006. An unusual archosaurian from the marine Triassic of China. *Naturwissenschaften* **93**, 200–6.

MASSARE, J. A. 1987. Tooth morphology and prey preference of Mesozoic marine reptiles. *Journal of Vertebrate Paleontology* **7**, 121–37.

MOTANI, R., JIANG, D. Y., TINTORI, A., SUN, Y. L., HAO, W. C., BOYD, A., HINIC-FRLOG, S., SCHMITZ, L., SHIN, J. Y. & SUN, Z. Y. 2008. Horizons and assemblages of Middle Triassic marine reptiles from Panxian, Guizhou, China. *Journal of Vertebrate Paleontology* **28**, 900–3.

PALMER, A. & GEISSMAN, J. 1999. *1999 Geologic Time Scale*. Boulder, Colorado: Geological Society of America.

SCHEYER, T. M., ROMANO, C., JENKS, J. & BUCHER, H. 2014. Early Triassic marine biotic recovery: the predators' perspective. *PLoS ONE* **9**, e88987.

SUN, Z. Y., SUN, Y. L., HAO, W. C. & JIANG, D. Y. 2006. Conodont evidence for the age of the Panxian Fauna, Guizhou, China. *Acta Geologica Sinica* **80**, 621–30.

WANG, Y., YANG, D., HAN, J. L. W., YAO, J. & LIU, D. M. 2014. The Triassic U–Pb age for the aquatic long-necked protorosaur of Guizhou, China. *Geological Magazine* **151**, 749–54.

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