Earth & Life (http://www.geofinds.com), (2006-10-1), 1(1): 1--6.

Lagged mass extinction in conodonts across the Permian-Triassic boundary

WU Ya Sheng[1*]

1. Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029
wys@mail.igcas.ac.cn

Abstract Earlier study on the Permian-Triassic boundary (PTB) sections in Meishan proposed that there were no mass extinction in conodonts across the PTB. Based on after-revision conodonts from the PTB sections in Meishan, Shangsi, and Kashmir, this study shows that there was a mass extinction in conodonts at the end of the Permian (between beds 26 and 27a of Meishan), which is later than the mass extinction of most other invertebrate groups at between beds 24e and 25 of Meishan. There are three evolutionary events in conodonts across the PTB. The first occurred at between beds 26 and 27a of Meishan, where most *Clarkina* components were replaced by *Hindeodus* components. The second event occurred at between beds 27b and 27c, where *Hindeodus* components with big cusp appeared. The third event occurred at between beds 27d and 28, where most *Hindeodus* components of Bed 27d disappeared.

Keywords: conodont; Permian-Triassic boundary; evolution; mass extinction

1. Introduction

The study of the geological events across the Permian-Triassic boundary (PTB) needs a time reference and conodont zones defined by the evolutionary events of conodonts (Yin et al., 1998, Yin et al., 2001.) are the most widely used relative time reference, except for absolute ages determined by zircon from the ash beds (Bowring et al., 1998., Mundil et al., 2004). The end-Permian mass extinction killed more than 90% of non-reef marine organisms (Erwin et al., 1993), 100% of reef marine organisms (Wu et al., 2002.), 70% of terrestrial vertebrates, and most land plants (Retallack, 1995). This death roll includes nearly all marine organisms but not conodonts. So, studies are need to find was there any mass extinction in conodonts across the PTB.

Jin et al. (2000) deal with the extinction pattern of most invertebrate groups in Meishan sections and found that the mass extinction is a sudden extinction at 251.4 Ma followed by gradual decline of some more taxa in the later 1 Ma. Was the mass extinction of conodonts, if it was present, also a sudden event?

* WU YS: PhD degree from Chinese Academy of Sciences. Associate Professor of Institute of Geology and Geophysics, Chinese Academy of Sciences. Have been doing Researches on Permian reefs, Permian-Triassic boundary since 1988.

The above questions depend on our understanding on the evolution of conodonts during the PTB. Many researchers have dealt with the evolution of conodonts across the PTB (Sweet, 1970; Clark et al., 1986; Tian, 1993; Ding et al, 1996; Mei et al, 1999; Yang et al., 1999; Lai et al., 2000.). Based on conodonts in Meishan sections, Clark et al. proposed that there was no mass extinction but reduction in abundance of conodonts across the PTB (Clark et al., 1986.). Erwin (1993) believed that conodonts are not influenced by the biotic crisis near the P/T boundary. After their work, however, more conodonts were described from the PTB sections in Meishan, Shangsi, and Kashmir (Zhang et al., 1995, 1996; Wang, 1995; Mei et al., 1998.), and their conclusions need updating. Ding et al. (1996) determined the lineage from *Hindeodus latidentatus* to *Hindeodus parvus*, which serves as the basis for definition of the beginning of the Triassic Period with the first appearance of the conodont *Hindeodus parvus* (Yin et al., 2001.). Kozur (1998) recognized three extinctions in conodonts in the PTB and Early Triassic: the first is the disappearance of warm- water adapted *Clarkina* components somewhat below the *H. parvus* zone, the second is the extinction of those adapted to both warm water and cool water at the base of *Isarcicella isarcica* zone, and the third is the disappearance of cool-water adapted *Hindeodus* conodonts in an above horizon.

Any studies of biotic evolution need reliable taxonomic data. During a recent study, we found that many conodonts from these PTB sections were incorrectly identified (Wu, 2005). For example, many specimens previously placed into *H. latidentatus* and *H. typicalis* (Zhang et al., 1996.) actually should be placed in other taxa. Incorrect identification may artificially elongate or shorten the ranges of some taxa and lead to bias in understanding of conodont evolution. To avoid such a bias and improve accuracy of evolutionary study and biostratigraphic studies, a revision on the incorrectly assigned conodonts is needed. Comparison of enlarged photo involved specimen with involved holotype shows more than 60 previously described conodonts from these PTB sections were incorrectly identified. We corrected all of them (Wu, 2005). This revision causes changes in geological ranges of many taxa (Fig. 1), which would lead to some different interpretation of the evolution of conodonts across the PTB.

2. Evolution of conodonts across the PTB

The PTB interval of Meishan is lithologically divided as 8 beds in ascending order: 24e, 25, 26, 27a, 27b, 27c, 27d, and 28 (Zhang et al., 1995.). Each bed has a thickness less than 10 cm. The following discussions on the evolution of PTB conodonts are based on all after-revision conodonts from Meishan, Shangsi, and Kashmir sections, but not Selong section in Xizang, since the conodonts of Selong section (Yao et al., 1987; Mei, 1996; Jin et al., 1996; Orchard et al., 1994, 1998) seems to belong to a different paleobiogeographic region.

As seen from Fig.1, Bed 24e contains only 4 species of conodonts. Three of them persisted into Bed 25. The survival rate (ratio of survival species to total species) is 75%. Thus, there are no big extinction between beds 24e and 25. The conodont species diversity in Bed 25 increased to 7 species, further indicating continuous development of conodonts from Bed 24e to Bed 25. Jin et al.'s study (2000) shows that most marine animal groups suffered a sudden mass extinction at between beds 24e and 25. Why conodonts did not suffer such an extinction? Did conodont animals have some special ecological particularity, which enable them to survive the crisis that had killed most other animals? If they have, what are them?

Bed 26 contains 12 conodont species, subspecies and potential new species. Compared to Bed 25, species diversity increased in Bed 26. Two species (*C. yini* and *H. inflatus*) of Bed 25 extended into Bed 26. The *Clarkina* component with deflected platform end (*C. reductus*) appeared in Bed 25 for the first time. In Bed 26, however, *Clarkina* components with deflected platform end developed into 4 species and subspecies (*C. deflecta* and *C. paradeflecta*). In addition, *Clarkina* components with branched carina end appeared in Bed 26 for the first time.

Beds 24e, 25, and 26 are composed of limestone, white claystone formed from ash, and black claystone, respectively. No mass extinction in conodonts is related to changes in lithology or sedimentary environments.

Eleven of the 12 *Clarkina* species of Bed 26 disappeared at between beds 26 and 27a. Only one species (*C. paradeflect*a) persisted into Bed 27a. The extinction ratio is as high as 92%, representing a mass extinction in conodonts. Besides *C. paradeflect*a, one *Hindeodus* species (*H. inflatus*) of Bed 26 lasted into Bed 27a.

Beds 27a and 27b contain 14 conodont species and subspecies. Twelve of them are *Hindeodus* components, 11 of which are new species. The most important components are *H. changxingensis* and *H. difformis*. The two *Clarkina* species include a new species (*C. elliptica*), and an old species lasting from Bed 26. The conodonts of Bed 27a-b are mostly new species, representing rapid recovery after the crisis.

The *Hindeodus* components of Beds 27a-b include three types: those with erect cusp but adenticualte top face, exampled by *H. changxingensis*; those with indistinct cusp but S-shaped oral margin, exampled by *H. zhejiangensis*; and those with a not very big cusp but erect denticles, as exampled by *H. limus*. The most important characteristic feature of the conodonts of these two beds is the absence of *Hindeodus* with parvus-type cusp (wider than denticles by more than 2~3 times).

Three of the 6 conodont species and subspecies of Bed 27b persisted into Bed 27c, with a survival ratio of 50%, indicating that there was no big extinction event at between beds 27b and 27c.

Beds 27c and 27d contain 18 conodont species, greatly increased in diversity than Beds 27a-b. Bed 27c contains 13 conodont species and subspecies, more than two times of that of Bed 27b, showing marked increase in conodont diversity from Bed 27b to Bed 27c.

The conodonts of Bed 27c is characterized by the appearance of many *Hindeodus* species with parvus-type cusp, for example, *H. parvus*, which appeared in this bed for the first time and reached worldwide distribution. Besides, the components with S-shaped oral margin and those with adenticulate top face continued to develop in this bed. Though there were no mass extinction between beds 27b and 27c, appearance of *Hindeodus* with parvus-type cusp makes the boundary between beds 27b and 27c an important biotic evolutionary boundary.

Bed 28 contains only 6 conodont species. Compared to Bed 27d, the conodont diversity of Bed 28 greatly dropped. *Hindeodus* components flourished in beds 27c and 27d suddenly disappeared in this bed. *H. parvus* is previously believed to last into Bed 28. But, in our opinion, they are not the same as those of Bed 27c-d. Besides, the components of *Isarcicella* and *Neospathodus* appeared characteristically for the first time. The change in conodonts from Bed 27d to Bed 28 indicates that the boundary between Beds 27d and 28 is a secondary biotic evolutionary boundary.

The conodonts of the PTB interval are characterized by one continuance, one mass extinction event, one rapid recovery, one flourishing, and one small extinction event. The conodonts of Bed 24e mostly continued to live in Beds 25, which is the continuance. The *Clarkina* components of Bed 26 mostly disappeared at between beds 26 and 27a, which is the mass extinction. The conodonts of Beds 27a-b have a diversity degree similar to that of Bed 26, representing the rapid recovery. The conodont fauna of Bed 27a-b was dominated by *Hindeoedus* components. Compared to Bed 27b, the conodonts of Bed 27c greatly increased in species diversity and many species with big cusp appeared, which was a flourishing. Most components of Bed 27d disappeared at between beds 27d and 28, which is a small extinction event.

Thus, the evolution of conodonts during the P-T boundary interval defines three biotic evolutionary boundaries: the most distinct one lies between beds 26 and 27a (Fig. 1, A), where *Clarkina* components of Bed 26 were mostly replaced by *Hindeodus* components. The second boundary of secondary order lies between beds 27b and 27c, above which *Hindeodus* with big cusp appeared. The third boundary of smaller magnitude lies between beds 27d and 28, where most *Hindeodus* components disappeared while *Isarcicella* and *Neospathodus* components appeared.

3. **Conclusions**

This study shows that there is one mass extinction in conodonts at the end of the Permian (between beds 26 and 27a of Meishan) and it was later than the mass extinction of most marine animal groups, which occurred at between beds 24e and 25 of Meishan. The lagged appearance of the mass extinction of conodonts may be related to some special ecological features of this kind of enigmatic organisms. Conodonts are nektonic, soft-bodied, probably surface or upper water heterotrophic organisms and probably shared space with a large number of invertebrate and vertebrate animals that went extinct earlier at the end of the Permian. We do not know what characteristics of conodonts shielded them from the fate of associated organisms and what made them suffer a mass extinction at a later moment.

The difference in mass extinction timing of conodonts and that of most other marine groups represent what intrinsic features of conodonts? More studies are needed to answer this question.

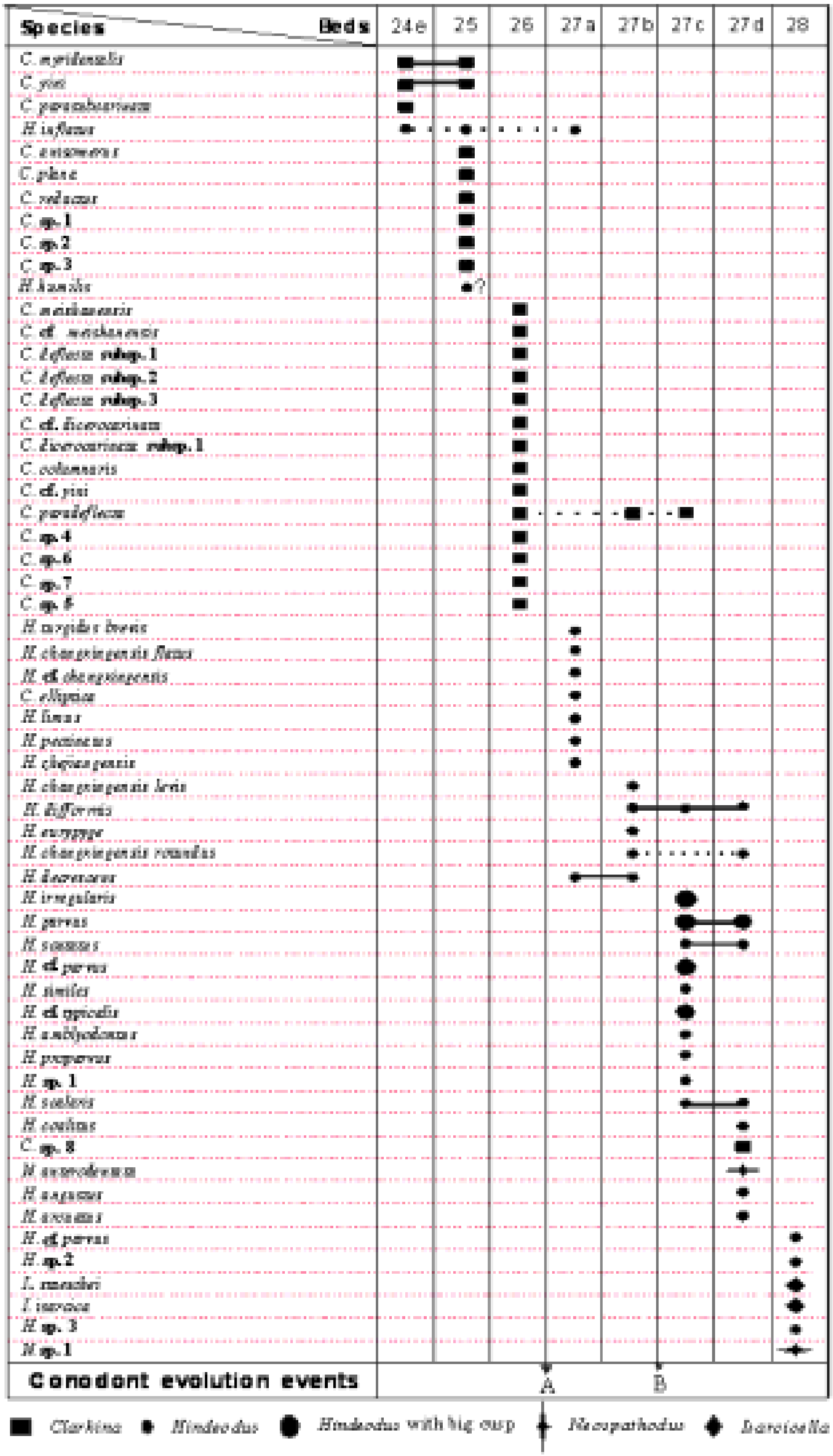

Fig. 1 Distribution ranges of conodonts across Permian-Triassic boundary. It shows three evolutionary events: (1) mass extinction of nearly all Clarkina components at between beds 26 and 27a, (2) appearance of Hindeodus components with big cusp since Bed 27c, (3) disappearance of most Hindeodus components at between beds 27d and 28.

Acknowledgements We thank passed paleontologist Y. G. Jin for assisting field investigation of Meishan section. Supported by National Natural Scientific Foundation of China (No. 40472015) and the State Key Laboratory of Modern Paleontology and Stratigraphy (No. 053102), as well as the Key Laboratory for Minerals and Resources, Chinese Academy of Sciences.

References

Bowring S.A., Erwin D.H., Jin Y.G., Martin M.W., Davidek K., Wang W., 1998. U/Pb zircon geochronology and tempo of the end-Permian mass extinction. Science 280: 1039-1044.

Clark D.L, Wang C.Y., Orth C.J, Gilmore J.S., 1986. Conodont survival and low iridium abundances across the Permian-Triassic boundary in South China. Science 233: 984-986.

Ding M.H., Zhang K.X., Lai X.L., 1996. Evolution of Clarkina lineage and Hindeodus-Isarcicella lineage at Meishan section, South China. In: Yin, H.F., ed., 1996. The Paleozoic-Mesozoic boundary. China University of Geosciences Press, p. 65-71.

Erwin D.H., 1993. The great Paleozoic crisis: life and death in the Permian. Columbia University Press, New York., 327 p.

Jin Y.G., Shen S.Z., Zhu Z.L., Mei S.L., Wang W., 1996. The Selong section, candidate of the Global Stratotype section and point of the Permian-Triassic boundary. In: Yin, H., ed., The Palaeozoic-Mesozoic boundary. Candidates of The Global Stratotype Section and Point of the Permian-Triassic Boundary. China University of Geosciences Press, p.127-135.

Jin Y.G., Wang Y., Wang W., Shang Q.H., Cao C.Q., Erwin D.H., 2000. Pattern of marine mass extinction near the Permian–Triassic boundary in South China. Science 289: 432–436.

Kozur H.W., 1998. Some aspects of the Permian–Triassic boundary (PTB) and of the possible causes for the biotic crisis around this boundary. Palaeogeography, Palaeoclimatology, Palaeoecology 143: 227-272.

Lai X.L., Mei S.L., 2000. On zonation and evolution of Permian and Triassic conodonts. In: H. Yin, J. M. Dickins, G. R. Shi and J. Tong, eds., Permian-Triassic Evolution of Tethys and Western Circum-Pacific. Elsevier Science, p. 371-392.

Mei S.L., 1996. Restudy of Conodonts from the Permian-Triassic boundary beds at Selong and Meishan and the natural Permian-Triassic boundary. In: Wang, H. and Wang, X., eds., Centennial Memorial Volume of Prof. Sun Yunshu, Palaeontology and Stratigraphy. China University of Geosciences Press, Beijing, p. 141-148.

Mei S.L., Shi X.Y., 1999. On evolution and zonation of Permian and early Triassic conodonts. In: Biotic and geological development of the Paleo-Tethys in China. Peking University Press, p. 113-121.

Mei S.L., Zhang K.X., Wardlaw B.R., 1998. A refined succession of Changhsingian and Griesbachian neogondolellid conodonts from the Meishan section, candidate of the global stratotype section and point of the Permian-Triassic boundary. Palaeogeography, paleoclimatology, Paleoecology 143: 213-226.

Mundil R., Ludwig K.R., Metcalfe I., Renne P.R., 2004. Age and timing of the Permian mass extinction: U/Pb dating of closed-system zircons. Science 305: 1760-1763.

Orchard M.J., Krystyn L., 1998. Conodonts of the lowermost Triassic of Spiti, and new zonation based on Neogondollela successions. Revista Italiana di Paleontologia Stratigraphia, 104(3): 341-368.

Orchard M.J., Nassichuk W.W., Rui L., 1994. Conodonts from the Lower Griesbachian Otoceras latilobatum Bed of Selong, Tibet and the position of the Permian-Triassic boundary. Canadian Society of Petroleum Geologists, Mem. 17: 823-843.

Retallack G.J., 1995. Permian-Triassic life crisis on land. Science 267: 77-80.

Sweet W.C., 1970. Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. In：Kummel, B., Teichert, C., eds., Stratigraphic Boundary Problems, Permian and Triassic of West Pakistan. Spec. Publ. Kansas Univ., Dept. Geol. 4: 207-275.

Tian S.G., 1993. The Permo–Triassic boundary and conodont zones in northwestern Hunan Province. Bulletin of Chinese Academy of Geological Sciences 26: 133-150. (in Chinese with English abstract)

Wang C.Y., 1995. Conodonts of Permian–Triassic boundary beds and biostratigraphic boundary. Acta Palaeontologica Sinica 34 (2): 129-151. (in Chinese with English abstract)

Wu Y.S., 2005. Conodonts, reef evolution and mass extinction across the Permian-Triassic boundary. Geological Publishing House, p. 1-90.

Wu Y.S., Fan J.S., 2002. Permian-Triassic history of reefal thalamid sponges:evolution and extinction. Acta Palaeontologica Sinica 41(2): 163-177. (in Chinese with English abstract)

Yang S.R., Hao W.C., Wan, X.P., 1999. Conodont evolutionary lineage, zonation and PT boundary at P-T boundary beds in Guangxi, China. In: Biotic and geological development of the Paleo-Tethys in China. Peking University Press, p. 81-95.

Yao J.X., Li Z.S., 1987. Permo-Triassic conodont [illegible] ry of Selong, Nielamu County, Tibet, China. Chinese Science Bulletin 32: 45-51.

Yin H.F., Tong J.N., 1998. Multidisciplinary high-resolution correlation of the Permian-Triassic boundary. Palaeogeography, Palaeoclimatology, Palaeoecology 143: 199-212.

Yin H.F., Zhang K.X., Tong J.N., Yang Z.Y., Wu S.B., 2001. The Global Stratotype Section and Point (GSSP) of the Permian-Triassic Boundary. Episodes 24 (2): 102-114.

Zhang K.X., Ding M.H., Lai X.L., Liu J.H., 1996. Conodont sequence of the Permian–Triassic boundary strata at Meishan section, South China. In: Yin, H.F., ed., The Palaeozoic–Mesozoic Boundary Candidates of Global Stratotype Section and Point of the Permian–Triassic Boundary. China University of Geosciences Press, Wuhan, p. 57-64.

Zhang K.X., Lai X.L., Ding M.H., Wu S.B., Liu J.H., 1995. Conodont sequence and its global correlation of Permian–Triassic boundary in the Meishan section, Changxing, Zhejiang Province. Earth Science-Journal of China University of Geosciences 20 (6): 669-676. (in Chinese with English abstract)

(Reviewer: Fan JS)