Publication Announcement

Early-Middle Triassic boundary interval: Integrated chemo-bio-magneto-stratigraphy of potential GSSPs for the base of the Anisian Stage in South China. By Yan Chen, Haishui Jiang, James G. Ogg, Yang Zhang, Yifan Gong, & Chunbo Yan, 2019. Earth and Planetary Science Letters, [access on-line 23 Oct 2019]. https://doi.org/10.1016/j.epsl.2019.115863
[Includes an additional 29-page PDF supplement, plus an Excel supplement of 7 worksheets including full demagnetization data for all samples, stable isotopes, TSCreator visualization datapacks, etc.]

Highlights

The Wantou section (Guangxi province) S. China) had been previously studied for ammonoid, conodont and carbon-isotope stratigraphy (Galfetti et al., 2007, 2008) and the main events and trends are bracketed by a succession of a dozen volcanic ashes that have yielded ID-TIMS U-Pb ages (Ovtcharova et al., 2006, 2015). This new study added a detailed magnetostratigraphy and enhanced the conodont and stable isotope stratigraphy for high-resolution global correlation, plus replicated the main magneto-biostratigraphic events in an additional section at Youping. The combined results indicate that the Wantou section is an ideal candidate for the Early-Middle Triassic boundary stratotype. The preferred level for the Anisian GSSP is a horizon that records the first *Chiosella timorensi*s s.str. conodont near the brief polarity chron MT1n.

Abstract—The Wantou and Youping sections of Guangxi, South China provide a detailed high-resolution integrated calibration of the Early-Middle Triassic boundary succession for lithostratigraphy, volcanic episodes, conodont first occurrences (FOs), ammonoid biostratigraphy, geomagnetic polarity, inorganic carbon isotopes, sea-surface temperatures derived from conodont-apatite oxygen-isotopes, and ID-TIMS U-Pb radiometric dating. The upper Spathian (late Early Triassic) magnetostratigraphy is characterized by normal polarity (magnetozone LT9n) that encompasses the FOs of the typical Spathian conodonts *Triassospathodus homeri* and *Gladigondolella carinata*, the late Spathian *Neopopanoceras haugi* ammonoid zone and the beginning of a progressive positive shift in inorganic carbon isotopes. The overlying reversed polarity interval (LT9r) contains two brief normal-polarity subzones (MT1n and MT2n) that can be recognized in several other marine and terrestrial sections. The FO of conodont *Chiosella timorensis* sensu stricto, a proposed base-Anisian global marker, is near MT1n and near the end of the positive $\delta^{13}C_{carb}$ excursion. Sea-surface temperatures were reported to have cooled by 4°C during this rise in $\delta^{13}C_{carb}$, suggesting a sequestration of carbon dioxide. The lowermost Anisian at Wantou and Youping is dominated by normal polarity (MT3n, with the presence of one major reversed-polarity subzone MT3n.1r), contains the FO of typical Anisian conodonts (*Gladigondolella tethydis*/*Magnigondolella alexanderi*), and has the onset of a plateau in inorganic carbon isotopes values (stabilizing around +4‰). The combination of the FO of conodont *Chiosella timorensis* s.str., the brief normal polarity zone (MT1n) and the last portion of the rising carbon-isotope trend are suitable for primary proxies for global correlation of the Early-Middle Triassic boundary (base of Anisian) to other marine and non-marine settings. Radiometric dates at the Wantou and at the Guandao sections, coupled with a composite cyclostratigraphy for Early Triassic through Anisian, indicate that the FO of the conodont *Chiosella timorensis* s.str. is at approximately 246.7 Ma.

Additional details and figures

The Wantou section (24.5915°N, 106.8625°E) at Jinya, Fengshan County, Guangxi province, South China, and the Youping section (24.9583°N, 206.5391°E), about 52 km northwest of the Wantou section (Fig. 1), have a similar lithological conformable succession of thick-bedded limestone with abundant bioclasts (Unit V of the Luolou Fm), transition beds of thin-bedded, siliceous mudstone containing calcareous nodules and the basal Baifeng Fm with laminated shale (Figs. 2 and 3). This succession is punctuated by a series of fine- and coarse- grained volcanic ash layers, of which the thickest are known informally as the "Green Bean Rock", that have yielded precise radiometric ages.

The conodont biostratigraphy at Wantou in this study embraced the Early-Middle Triassic boundary conodont faunal turnover from previous studies, which is the complete replacement of late Spathian assemblages of *Triassospathodus*, *Spathicuspus* and *Novispathodus* by basal Anisian fauna of *Gladigondolella*, *Chiosella* and *Neogondolella* (*Magnigondolella*). There are five conodont appearance events identified as expedient in constraining the boundary interval in the Wantou and on a global scale. They are, in ascending order: FO of *Tr. homeri*/*Tr.* ex gr. *homeri*; FO of *Gl. carinata*; FO of *Ch. timorensis* s.str.; FO of *Gl. tethydis*; and FO of *Magnigondolella alexanderi*/*Ng.* ex gr. *regalis* (Fig. 2).

The Wantou section is dominated by normal polarity, with one significant reversed-polarity zone spanning the EMTB interval and another at the top (WT2r). The overall generalized polarity pattern is consistent with the cycle-tuned geomagnetic polarity time scale (GPTS) for the Early-Middle Triassic (Hounslow and Muttoni, 2010; Li et al., 2016, 2018; Ogg et al., 2016). Based on the conodont distribution and inorganic carbon isotope trends, polarity zone WT1n is equivalent to LT9n of Hounslow and Muttoni (2010), subzone WT1r.4n as MT1n, WT1r.7n as MT2n, and WT2n as MT3n (Fig. 2). The WT1r (EMTB interval) contains multiple normal-polarity subzones, of which two (WT1r.4n, WT1r.7n) are documented by multiple paleomagnetic samples and are considered coeval with MT1n and MT2n of Hounslow and Muttoni (2010) with global correlation potential (Fig. 2).

Published online: December 9, 2019

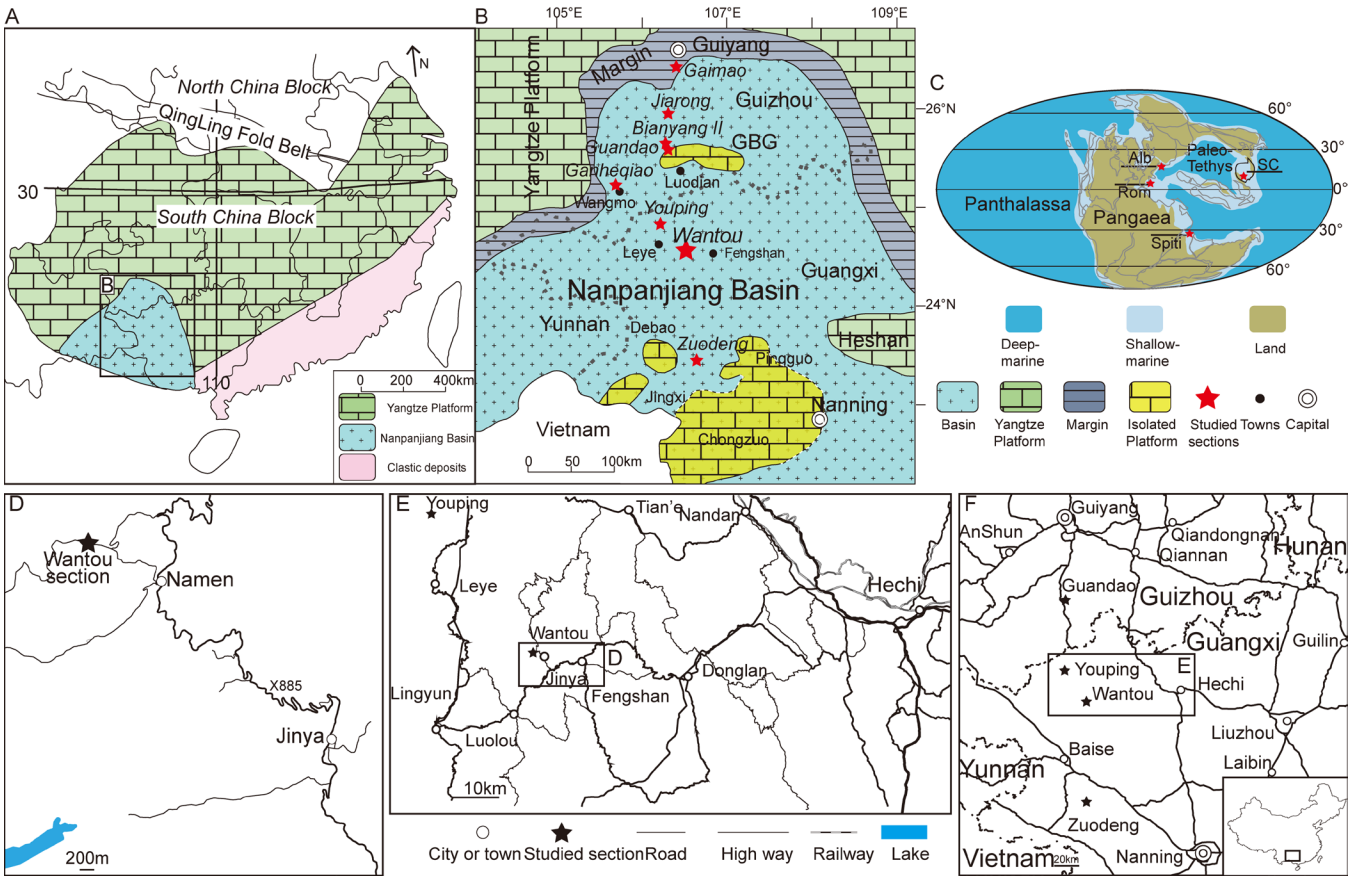

Figure 1 – Paleogeographic context and location of Wantou section. ***A***,***B***, Early-Middle Triassic paleogeography map of Yangtze Block (***A***) and Nanpanjiang Basin (***B***) (modified from Lehrmann et al. (2015), indicating previous studies (red stars) across the EMTB, including Wantou. ***C***, Early-Middle Triassic paleogeography (modified from http://www.scotese.com). Red dots show paleo-positions of research areas: SC= South China; Rom= Romania; Alb= Albania; Spiti= North India. ***D***,***E***,***F***, Locations of Wantou section. ***D***, Jinya town to Wantou section, which is an enlarged portion of map (***E***) of Fengshan Country to Jinya town and Wantou section. ***F***, Locations relative to the Nanning province capital and Hechi city. (Base maps modified from https://map.baidu.com)

The late Spathian positive carbon isotope shift followed by an early Anisian plateau has been documented at Losar, North India (Galfetti et al., 2007), Deşli Caira, Romania (Grădinaru et al., 2007), Guandao, South China (Lehrmann et al., 2015) and at Wantou (Ovtcharova et al., 2015; and this study). The beginning of the $\delta^{13}C_{carb}$ plateau is near the base of polarity zone WT2n (= chron MT3n of Hounslow and Muttoni, 2010) (Fig. 2) and slightly above the FO of *Ch. timorensis* s.str. at Guandao, Wantou and Deşli Caria.

The combination of potential global isochronous markers includes magnetic polarity chrons, conodont occurrences (the FO of *Ch. timorensis* s.str., the preferred potential proxy in this study for the Anisian GSSP level, is at about 20% up within the reversed-polarity subchron MT1r between the brief MT1n and MT2n), typical ammonoid occurrences (the FO of *Ch. timorensis* s.str. level is 1.3 m above the last occurrence of *Neopopanoceras haugi*), carbon isotopes (the FO of *Ch. timorensis* s.str. level is 0.74 m below the peak of a significant positive excursion) (Fig. 2), and an age model from the combination of U-Pb dates with regional cyclostratigraphy (the FO of *Ch. timorensis* s.str. is projected to be at approximately 246.7 Ma).

This combination implies that the Wantou outcrops of Guangxi, South China, have great potential as the GSSP reference section for the Early-Middle Triassic boundary and can enable precise global correlation into different facies.

A formal GSSP proposal is being prepared by this group in coordination with the other teams that have studied this section, and a potential Anisian working-group field meeting is being planned for May-June of 2020 in association with a Geobiology Congress in Wuhan, China.

References

Galfetti, T., Bucher, H., Brayard, A., Hochuli, P.A., Weissert, H., Kuang, G.D., Atudorei, V., & Guex, J., 2007a. Late Early Triassic climate change: Insights from carbonate carbon isotopes, sedimentary evolution and ammonoid paleobiogeography. Palaeogeography Palaeoclimatology Palaeoecology, 243(3-4): 394-411. https://doi.org/10.1016/j.palaeo.2006.08.014

Galfetti, T., Bucher, H., Martini, R., Hochuli, P.A., Weissert, H., Crasquin-Soleau, S., Brayard, A., Goudemand, N., Bruehwiler, T., & Kuang, G.D., 2008. Evolution of Early Triassic outer platform paleoenvironments in the Nanpanjiang Basin (South China) and their significance for

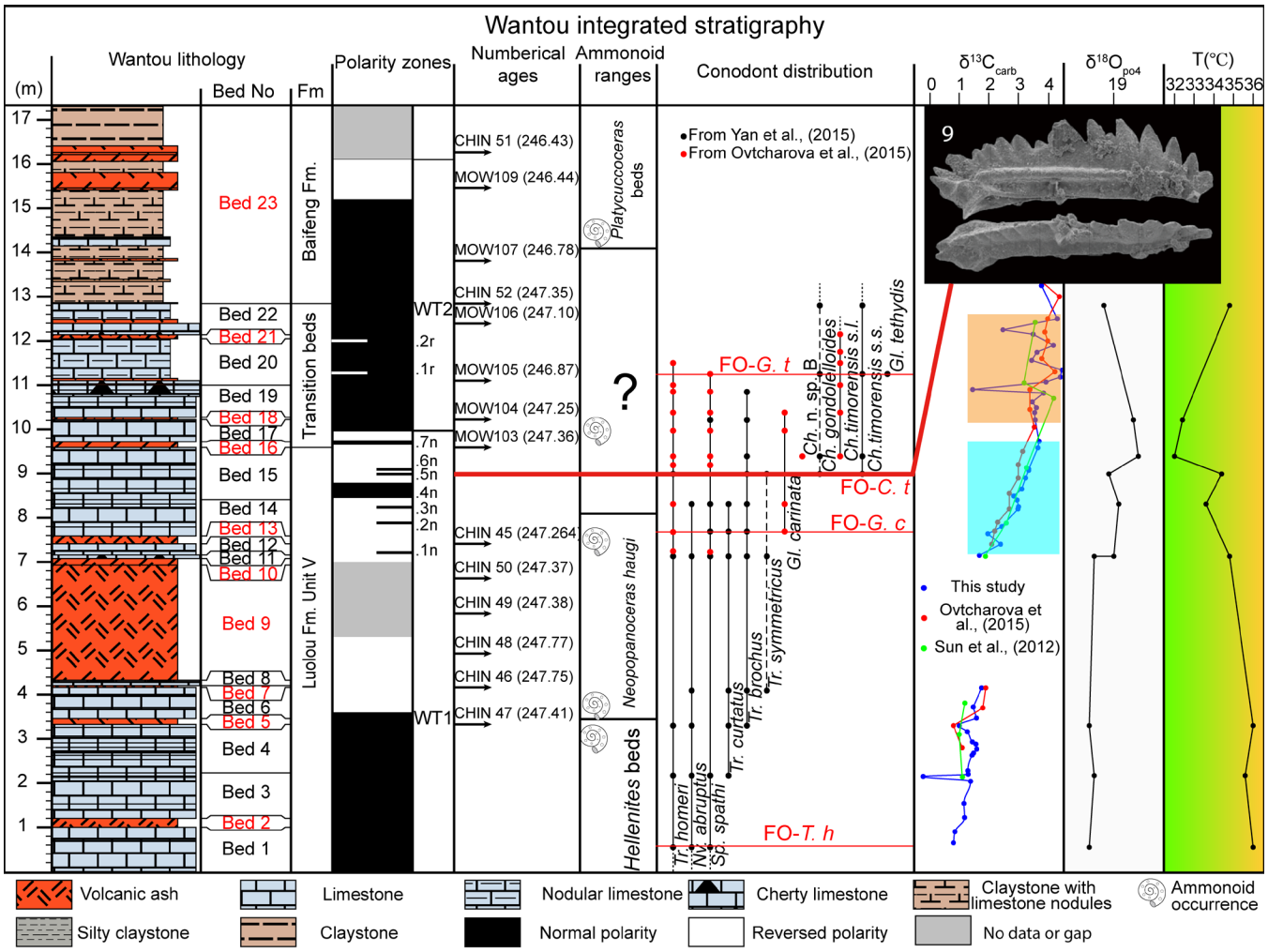

Figure 2 – Integrated stratigraphy of the Wantou section with magnetic polarity zones (this study; black is normal polarity, white is reversed), U-Pb dates from zircons (Ovtcharova et al., 2015), ammonoid zones (Galfetti et al., 2008), conodont ranges and datums (Ovtcharova et al., 2015; Yan et al., 2015), $\delta^{13}C_{carb}$ curve (Ovtcharova et al., 2015; Sun et al., 2012, and this study), and $\delta^{18}O$ and interpreted sea-surface temperatures from conodont apatite (Sun et al., 2012). Beds of volcanic ash in the lithology column have their names in red. Positive shift in $\delta^{13}C_{carb}$ is highlighted by blue, and the plateau is marked by orange. Conodont abbreviations: FO-*T. h* = first occurrence (FO) of *Tr. homeri*; FO-*G. c* = First occurrence of *Gl. carinata*; FO-*C. t* = First occurrence of *Ch. timorensis* sensu stricto; FO-*G. t* = First occurrence of *Gl. tethydis*; FO-*M. a* = First occurrence of *M. alexander*, *Ch.* = *Chiosella*, *Tr.* = *Triassospathodus*, *Nv.* = *Novispathodus*, *Gl.* = *Gladigondolella*, *M.* = *Magnigondolella*, *Sp.* = *Spathicuspus*. The photo of conodont *Ch. timorensis*. s.str. is from Yan et al. (2015).

the biotic recovery. Sedimentary Geology, 204(1-2): 36-60. https://doi.org/10.1016/j.sedgeo.2007.12.008

Grădinaru, E., Kozur, H., Nicora, A., & Orchard, M.J, 2006. The *Chiosella timorensis* lineage and correlation of the ammonoids and conodonts around the base of the Anisian in the GSSP candidate at Desli Caira (North Dobrogea, Romania). Albertiana, 34: 34-39.

Hounslow, M.W., and Muttoni, G., 2010. The geomagnetic polarity timescale for the Triassic: linkage to stage boundary definitions. Geological Society, London, Special Publications, 334(1): 61-102. https://doi.org/10.1144/sp334.4

Lehrmann, D.J., Stepchinski, L., Altiner, D., Orchard, M.J., Montgomery, P., Enos, P., Ellwood, B.B., Bowring, S.A., Ramezani, J., Wang, H.M., Wei, J.Y., Yu, M.Y., Griffiths, J.D., Minzoni, M., Schaal, E.K., Li, X.W., Meyer, K.M., & Payne, J.L., 2015. An integrated biostratigraphy (conodonts and foraminifers) and chronostratigraphy (paleomagnetic reversals, magnetic susceptibility, elemental chemistry, carbon isotopes and geochronology) for the Permian-Upper Triassic strata of Guandao section, Nanpanjiang Basin, South China. Journal of Asian Earth Sciences, 108: 117-135. https://doi.org/10.1016/j.jseaes.2015.04.030

Li, M.S., Huang, C.J., Hinnov, L.A., Chen, W.Z., Ogg, J.G., & Tian, W., 2018. Astrochronology of the Anisian stage (Middle Triassic) at the Guandao reference section, South China. Earth and Planetary Science Letters, 482: 591-606. https://doi.org/10.1016/j.epsl.2017.11.042

Li, M.S., Ogg, J.G., Zhang, Y., Huang, C.J., Hinnov, L.A., Chen, Z.Q., & Zou, Z.Y., 2016. Astronomical tuning of the end-Permian extinction and the Early Triassic Epoch of South China and Germany. Earth and Planetary

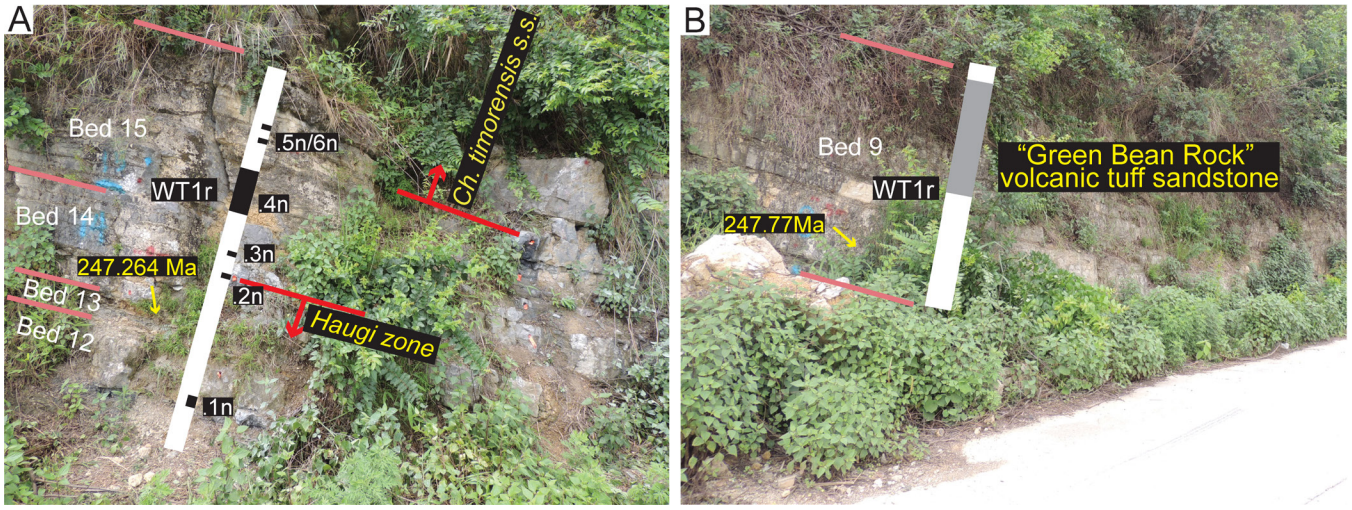

Figure 3 – Field photographs focusing on the Early-Middle Triassic Boundary interval in the Wantou (***A***,***B***), with bed numbers (white font and pink lines), occurrence of thick bed of volcaniclastic sandstone (Green-bean Rock; B; Bed 9), U-Pb dated levels (yellow numbers in ***A*** and ***B***), FOs of conodont (red upward arrows with yellow labels), and highest occurrence of the ammonoid *Neopopanoceras haugi* (red downward arrow with yellow label in ***A***), Conodont abbreviations: *Ch. timorensis* s.s.= *Ch. timorensis* sensu stricto. Polarity zone WT1r.4n is equivalent to chron MT1n of Hounslow and Muttoni (2010). See Fig. 2 for meter scale of the beds.

Science Letters, 441: 10-25. https://doi.org/10.1016/j.epsl.2016.02.017

Ogg, J.G., Ogg, G.M., and Gradstein, F.M., 2016. A Concise Geological Timescale 2016: Elsevier, 234 pp. ISBN 9780444637710.

Ovtcharova, M., Bucher, H., Schaltegger, U., Galfetti, T., Brayard, A., & Guex, J., 2006. New Early to Middle Triassic U–Pb ages from South China: calibration with ammonoid biochronozones and implications for the timing of the Triassic biotic recovery. Earth and Planetary Science Letters, 243(3-4): 463-475. https://doi.org/10.1016/j.epsl.2006.01.042

Ovtcharova, M., Goudemand, N., Hammer, Ø., Kuang, G.D., Cordey, F., Galfetti, T., Schaltegger, U., & Bucher, H., 2015. Developing a strategy for accurate definition of a geological boundary through radio-isotopic and biochronological dating: The Early-Middle Triassic boundary (South China). Earth-Science Reviews, 146: 65-76. https://doi.org/10.1016/j.earscirev.2015.03.006

Sun, Y.D., Joachimski, M.M., Wignall, P.B., Yan, C.B., Chen, Y.L., Jiang, H.S., Wang, L.N., & Lai, X.L., 2012. Lethally hot temperatures during the Early Triassic greenhouse. Science, 338(6105): 366-70. https://doi.org/10.1126/science.1224126

Yan, C.B., Jiang, H.S., Lai, X.L., Sun, Y.D., Yang, B., and Wang, L.N., 2015. The Relationship between the "Green-bean Rock" layers and conodont *Chiosella timorensis* and implications on defining the Early-Middle Triassic boundary in the Nanpanjiang Basin, South China. Journal of Earth Science, 26(2): 236-245. https://doi.org/10.1007/s12583-015-0535-x