



Liu, J., Hu, S-X., Rieppel, O., Jiang, D-Y., Benton, M. J., Kelley, N. P., Aitchison, J. C., Zhou, C-Y., Wen, W., Huang, J-Y., Xie, T., & Lv, T. (2014). A gigantic nothosaur (Reptilia: Sauropterygia) from the Middle Triassic of SW China and its implication for the Triassic biotic recovery. *Scientific Reports*, 4, [7142].
<https://doi.org/10.1038/srep07142>

Publisher's PDF, also known as Version of record

License (if available):
CC BY

Link to published version (if available):
[10.1038/srep07142](https://doi.org/10.1038/srep07142)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the final published version of the article (version of record). It first appeared online via Nature at <https://www.nature.com/articles/srep07142>. Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

Supplementary Information

A gigantic nothosaur (Reptilia: Sauropterygia) from the Middle Triassic of SW China and its implication for the Triassic biotic recovery

Jun Liu^{1,2,3}, Shi-xue Hu¹, Olivier Rieppel⁴, Da-yong Jiang⁵, Michael J. Benton⁶, Neil P. Kelley⁷, Jonathan C. Aitchison⁸, Chang-yong Zhou¹, Wen Wen¹, Jin-yuan Huang¹, Tao Xie¹ and Tao Lv¹

¹Chengdu Center, China Geological Survey, Chengdu 610081, China;

²School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 230009, China;

³State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, CAS, Nanjing 210008, China;

⁴Center of Integrative Research, The Field Museum, Chicago, IL 60605-2496, USA;

⁵Department of Geology and Geological Museum, Peking University, Beijing 100871, China;

⁶School of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, UK;

⁷Department of Paleobiology, National Museum of Natural History, Washington DC 20013, USA.

⁸School of Geosciences, The University of Sydney, Sydney, NSW 2006, Australia.

Correspondence and requests for materials should be addressed to J.L. (email: junliu@hfut.edu.cn).

Supplementary Note

Character Description. Characters are a combination of the phylogenetically informative characters for resolving the phylogenetic interrelationships of *Nothosaurus*⁵⁵ and *Lariosaurus*²⁷ with some minor revisions, as well as 20 new morphological characters that have not been used previously. If a character is originally from ref. 55 or ref. 27, it is noted as either R01 or R03 in the text.

1. Ratio, condylobasal skull length divided by longitudinal diameter of upper temporal fossa (modified from R01, Character 16):
 0. more than 3.8
 1. 3.0-3.4
 2. less than 2.9

2. Ratio of longitudinal diameter, upper temporal fossa to orbit (modified from R03, Character 13):
 0. less than 1.2
 1. 1.4-1.8
 2. 1.9-2.2
 3. 2.4-3.0
 4. more than 3.2

3. Ratio, the distance from the snout to the anterior margin of the internal naris divided by the distance from the snout to the anterior margin of the external naris

(modified from R01, Character 6):

0. smaller than 1.2
 1. larger than 1.3
4. Ratio, distance from posterior margin of external naris to anterior margin of orbit divided by the width of the postorbital arch (modified from R01, Character 13):
0. more than 1.7
 1. less than 1.5
5. Snout (R03, Character 3):
0. unstricted
 1. constricted
6. Rostrum (modified from R01, Character 1):
0. short and rounded
 1. long, slender and parallel-edged
7. Premaxilla(e) in adult:
0. paired
 1. partly or fully fused
8. Maxilla, depression at lateral margin of external naris and a foramen at its bottom for the exit of a lateral branch of the superior alveolar nerve (R01, Character 5):

- 0. absent
 - 1. present
9. Nasals in adult:
- 0. paired
 - 1. fused
10. Nasal(s) (R03, Character 8):
- 0. meeting each other
 - 1. seperated from one another by nasal processes of the premaxillae
extending back to the frontal bone(s)
11. Nasal, anterolateral process lining the entire medial margin of external naris (R01, Character 4):
- 0. absent
 - 1. present
12. Nasal, length behind level of posterior margin of external naris more than twice of the maximal width (R01, Character 7):
- 0. absent
 - 1. present
13. Nasals (modified from R03, Character 6):

- 0. large
 - 1. small
14. Nasal-prefrontal contact:
- 0. present
 - 1. absent
15. Pineal foramen (modified from R01, Character 23):
- 0. close to the middle of the parietal skull table
 - 1. displaced posteriorly
16. Pineal foramen located within a deep trough:
- 0. absent
 - 1. present
17. Parietal extending beyond the anterior margin of upper temporal fossa (modified from R01, Character 20):
- 0. present
 - 1. absent
18. Parietal skull table (R01, Character 22):
- 0. broad
 - 1. weakly constricted

- 2. strongly constricted

- 19. Parietal skull table, constriction in the posteriormost part:
 - 0. absent
 - 1. present

- 20. Dorsal exposure of prefrontal (R01, Character 8):
 - 0. large
 - 1. reduced

- 21. Jugal (modified from R01, Character 14):
 - 0. present
 - 1. absent

- 22. Jugal (modified from R01, Character 14):
 - 0. entering orbit
 - 1. excluded from posterior margin of orbit

- 23. Jugal-squamosal contact:
 - 0. absent
 - 1. present

- 24. Postfrontal, shape (modified from R03, Character 26):

- 0. elongated
 - 1. triradiate
25. Postfrontal, distinct constriction behind the orbit:
- 0. absent
 - 1. present
26. Postfrontal (R01, Character 10):
- 0. entering upper temporal fossa
 - 1. excluded from upper temporal fossa
27. Postorbital, forming the entire anterior margin of the upper temporal fossa (R01, Character 12):
- 0. absent
 - 1. present
28. Upper temporal fenestra, constriction of anterior corner (modified from R01, Character 18):
- 0. absent
 - 1. present
29. Quadratojugal (R03, Character 29):
- 0. present

1. absent
30. Pterygoid-ectopterygoid transverse flanges (Rieppel, 2003, character 44):
0. well developed
 1. strongly reduced
31. Occipital crest (R01, Character 24):
0. absent
 1. present
32. Supraoccipital, sagittal crest:
0. absent
 1. reduced
 2. well developed
 3. knob-like
33. Mandibular articulations (R03, Character 33):
0. approximately level with occipital condyle
 1. displaced to a level distinctly behind occipital condyle
34. Mandible, constriction:
0. absent
 1. present

35. Mandibular symphysis (modified from R03, Character 51):
- 0. short
 - 1. long
36. Mandibular symphysis, anterior fusion in adult:
- 0. absent
 - 1. present
37. Splenial (R03, Character 52):
- 0. entering mandibular symphysis
 - 1. excluded from mandibular symphysis
38. Splenial, posterior extension:
- 0. long
 - 1. short
39. Retroarticular process:
- 0. short
 - 1. long
40. Retroarticular process dorsal surface, foramen for the innervation of chorda tympani nerve:

- 0. absent
 - 1. present
41. Retroarticular process, trough on lateral surface for the insertion of the depressor mandibulae muscle/superficial pterygoideus muscle:
- 0. absent
 - 1. weak
 - 2. strong
42. Retroarticular process, trough on medial surface for the insertion of posterior fibers of pterygoideus internus muscle:
- 0. absent
 - 1. present
43. Dentary fangs:
- 0. absent
 - 1. present but less than 5
 - 2. 5
44. Premaxillary teeth:
- 0. more than 5
 - 1. 5

45. Premaxillary fangs (modified from R01, Character 2):
0. absent
 1. present but less than 5
 2. 5 or more
46. Number of small maxillary teeth anterior to the maxillary fang(s):
0. 3 or less
 1. 4
 2. 5 or more
47. Posterior extension of the maxillary tooth row (modified from R03, Character 57):
0. no more than sixty percent of the skull length (snout tip to posterior margin of quadrate)
 1. more than sixty-five percent of the skull length
48. Neural spines on dorsal vertebrae (modified from R01, Character 25):
0. low
 1. tall
49. Elongation of neural spines in proximal tail region (R03, Character 125):
0. absent
 1. present

50. Zygapophyseal pachyostosis (R03, Character 69):
- 0. absent
 - 1. present
51. Pachyostosis of dorsal ribs (R03, Character 72):
- 0. absent
 - 1. present
52. The number of sacral ribs (modified from R03, Character 73):
- 0. three
 - 1. four
 - 2. five
53. Medial gastral rib elements, lateral process (R03, Character 119):
- 0. all single
 - 1. may two-pronged
54. Clavicles, medially (R03, Character 77):
- 0. broad
 - 1. narrow
55. Clavicles (R03, Character 79):
- 0. do not meet in front of the interclavicle

1. meet in an interdigitating anteromedial suture
56. Clavicles, anterolaterally expanded corners (R03, Character 80):
0. absent
 1. present
57. Interclavicle (R03, Character 82):
0. rhomboidal
 1. T-shaped
 2. triangular
58. Humerus, proximal width compared with the mid-shaft (R03, Character 123):
0. greater
 1. less
59. Humerus, preaxial margin of shaft in dorso-ventral view:
0. with straight angle
 1. smoothly curved
60. Humerus, insertional crest for latissimus dorsi muscle (R03, character 94):
0. reduced
 1. prominent

61. Humerus, ectepicondylar groove (R03, Character 96):
0. open and notched anteriorly
 1. open without anterior notch
62. Humerus, entepicondylar foramen (R03, Character 97):
0. present
 1. absent
63. Radius, compared with ulna (R03, Character 98):
0. shorter
 1. longer
 2. approximately of the same length
64. Ulna, mid-diaphysis (R03, Character 120):
0. slender
 1. broadened
65. Ulna, distinctly broadened proximal head (R03, Character 121):
0. absent
 1. present
66. Ulna, anterior margin:
0. smoothly concave

1. with a tuberosity
-
67. Carpal ossifications, number (R03, Character 124):
 0. more than three
 1. three or less
-
68. Hyperphalangy in manus (R03, Character 122):
 0. absent
 1. present
-
69. Ilium, iliac blade (R03, Character 99):
 0. present
 1. absent (i.e., reduced to simple dorsal stub)
-
70. Pubis, ventral (medial) margin (R03, Character 100):
 0. convex
 1. concave
-
71. Pubis, obturator foramen in adult (R03, Character 101):
 0. closed
 1. open
-
72. Femur, internal trochanter (R03, Character 105):

- 0. well developed
 - 1. reduced
73. Femur, intertrochanteric fossa (R03, Character 106):
- 0. rudimentary or absent
 - 1. distinct but reduced
74. Total number of tarsal ossifications (R03, Character 115):
- 0. four or more
 - 1. three
 - 2. two

Character Coding. If a character state is unknown for a taxon, it is coded as ?. If a character is not applicable for a taxon, it is coded as -. Both states, however, will be treated as unknown by PAUP in the phylogenetical analysis.

Pachypleurosauria

0	0	0	0	0	0	?	0	0	0	0	1	0	?	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	0	?	1	0	0	0	0	0
0	0	0	0	0	0	?	0	0	0	0	1	0	0	0	0	1	1	1
0	0	0	0	0	1	0	0	0	1	0	?	0	0	1	0	0		

Simosaurus

2	2	1	0	0	0	0	0	0	1	0	0	1	?	1	0	1	1	0
0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1	0
0	1	2	1	0	1	0	-	1	0	0	0	0	0	1	0	1	1	1
0	0	0	1	1	2	0	1	0	1	0	0	1	0	1	0	0		

Germanosaurus

2	2	1	1	1	0	1	0	0	1	0	1	1	1	1	0	0	1	1
1	0	1	1	1	1	0	0	0	?	?	0	?	?	?	?	?	?	?
?	?	?	?	?	1	?	?	?	0	?	?	?	?	?	?	?	?	?
?	?	?	?	?	?	0	?	?	?	?	?	?	?	?	?	?	?	?

N. winkelhorsti

1	1	?	1	1	0	1	1	1	0	0	1	0	1	0	0	0	0	0
1	0	1	1	1	0	1	1	1	1	1	1	2	0	?	?	?	?	?

? ? ? ? ? 1 1 0 0 ? ? ? ? ? ? ? ? ? ?
 ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

N. yangjuanensis

2 3 0 1 1 0 0 1 0 0 0 0 0 0 1 0 1 2 1
 1 0 1 0 1 1 1 1 0 ? 1 1 2 0 ? ? ? ? ?
 1 0 2 1 ? 1 1 2 0 0 1 0 0 1 1 0 0 1 0
 1 0 1 0 0 2 1 1 1 0 1 0 1 0 0 0 1

N. marchicus

2 3 0 1 1 0 0 1 0 0 1 0 0 1 1 0 ? 2 ?
 1 0 1 1 ? 1 ? ? ? 1 1 1 1 0 1 0 1 ? ?
 1 ? ? ? ? 1 2 2 0 0 ? 1 0 0 1 ? ? ? ?
 1 0 1 0 0 2 0 ? 0 1 ? ? 1 0 1 ? 1

N. mirabilis

2 4 0 1 1 1 0 1 0 0 1 1 0 1 1 0 1 2 ?
 1 0 ? ? 0 0 1 1 1 1 1 1 1 0 1 1 1 1 1
 1 ? ? ? 2 1 2 ? 1 1 ? 1 ? ? ? 0 1 1 1
 0 0 1 0 0 ? 0 ? ? ? ? ? 1 ? ? ? ?

N. juvenilis

1 1 ? 0 1 1 0 1 0 0 1 1 0 0 1 0 0 1 0
 1 0 1 0 1 0 0 0 0 1 ? 1 1 0 ? ? ? ? ?
 ? ? ? ? ? 1 ? 0 1 0 ? ? ? ? ? ? ? ? ?
 ? ? ? ? ? ? 0 1 ? ? ? 0 1 1 ? ? ?

N. giganteus

2 4 0 1 1 0 0 1 0 0 1 1 0 1 1 0 1 1 0
1 0 1 ? ? 0 ? 1 1 1 0 1 1 0 1 ? 1 1 ?
1 0 2 1 2 1 1 1 0 0 0 1 0 2 1 1 0 1 0
0 0 1 1 0 2 1 1 ? 0 0 0 1 0 ? ? 1

N. zhangii

? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?
? ? ? ? ? ? ? ? ? ? ? ? ? ? 1 0 1 1 0
0 ? ? 1 ? ? ? ? ? ? 0 ? ? 0 ? ? ? ? ? ?
? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

N. tchernovi

2 3 0 1 1 1 0 0 0 0 1 1 0 0 1 0 1 2 1
1 1 - - 0 0 ? 1 1 1 1 1 1 ? 0 1 1 ? ? ?
? ? 2 ? 2 1 2 1 1 1 1 1 ? ? ? ? ? ? ?
0 0 1 1 0 ? ? ? ? ? ? ? ? ? ? ? ?

N. haasi

0 2 0 0 1 1 0 0 0 1 0 1 1 1 1 0 1 2 1
1 1 - - 1 0 0 0 0 1 1 1 2 0 ? ? ? ? ?
? ? ? ? ? 1 2 0 1 1 ? ? ? ? ? ? ? ? ?
1 1 1 1 0 ? ? ? ? ? ? ? ? ? 0 1 ?

N. youngi

2 2 0 0 1 0 0 1 0 0 0 1 0 0 1 1 0 2 0

1	0	1	0	1	0	1	1	1	1	0	1	1	0	0	0	0	1
1	1	1	1	1	1	2	0	0	0	0	1	1	?	1	0	0	2
0	?	0	?	?	2	1	?	1	0	?	1	0	0	0	0	1	

N. jagisteus

2	3	0	1	1	1	0	1	0	0	1	1	0	1	1	0	1	2	1
1	0	1	0	1	0	1	1	0	1	0	1	1	0	1	1	1	1	1
1	?	2	1	1	1	2	1	1	0	?	?	0	?	1	0	1	1	1
0	0	1	1	0	0	0	0	0	1	?	?	1	1	?	?	?		

N. edingerae

2	3	0	0	?	0	0	0	?	?	1	0	0	?	1	1	1	2	1
1	?	?	?	1	0	0	1	1	?	1	1	?	?	?	?	?	?	?
?	?	?	?	?	1	?	0	?	0	?	?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

L. hongguoensis

1	2	0	0	1	0	0	0	?	0	1	?	?	1	1	1	0	1	0
1	0	1	0	1	0	1	1	0	0	0	1	1	0	1	0	0	0	1
1	1	0	0	?	0	2	0	0	?	?	?	?	?	1	?	?	0	?
0	1	1	?	0	2	1	0	0	0	1	?	0	1	1	0	2		

L. buzzii

0	0	0	0	1	0	1	1	1	0	0	1	0	1	0	0	0	1	0
1	?	?	?	1	0	0	0	0	1	1	1	2	0	1	0	0	1	?
1	1	?	?	1	1	?	?	0	0	0	1	0	?	0	1	0	0	?

0 0 0 1 1 1 1 ? 0 ? ? 1 0 1 1 0 ?

L. calcagnii

0 0 0 1 0 0 0 ? 0 0 0 ? 0 0 1 0 1 2 1

0 0 ? 0 0 0 0 0 0 1 1 1 ? 0 0 1 0 1 ?

1 ? ? ? 2 ? ? ? ? 0 1 1 0 2 0 1 0 1 0

1 1 0 1 0 2 1 0 0 0 1 1 1 1 1 0 1

L. curionii

1 1 0 0 0 0 0 ? 0 1 1 1 0 ? 1 0 ? 2 1

1 ? ? ? 0 0 1 1 1 1 1 1 0 0 0 0 ? 1 ?

1 ? 2 ? 2 0 ? 0 0 0 0 1 1 ? ? 0 1 1 0

1 1 0 1 0 0 1 1 1 ? ? ? ? ? ? ? ?

L. balsami

1 1 0 0 1 0 0 ? 0 1 0 ? 0 ? 1 0 0 2 1

? 0 0 1 0 0 ? ? 0 ? 1 1 2 0 0 0 0 1 ?

1 ? 2 ? ? ? ? ? ? 0 0 1 ? 1 0 0 1 1 0

1 1 0 1 ? ? 1 1 0 0 1 1 0 1 1 0 ?

L. valceresii

1 2 ? 1 1 0 0 ? 0 0 0 0 0 0 1 0 1 2 1

0 ? ? 0 0 0 0 0 0 1 1 1 0 0 ? ? ? 1 ?

1 ? 1 ? ? 0 2 ? ? 0 0 1 0 1 0 ? ? ? ?

1 0 0 0 0 2 1 1 1 0 1 1 0 ? 1 0 2

L. xingyiensis

2	2	0	0	1	0	0	1	0	0	1	0	0	0	1	0	0	2	1
0	?	1	0	1	0	1	1	1	?	0	1	2	0	1	1	0	1	0
1	1	1	1	2	1	?	0	0	0	1	1	1	2	0	1	0	0	0
1	0	0	0	0	2	1	1	1	0	1	1	?	?	0	1	?		