SUPPLEMENTARY ONLINE MATERIAL FOR

A new Early Devonian antiarch (Placodermi) from Belarus, and

phylogeny of Asterolepidoidei

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Supplementary Online Material

**SOM 1.** Phylogenetic Analysis of Antiarchi (modified from Wang & Zhu 2018)

1) Character list
2) Data matrix with 80 morphological characters for 47 taxa

**SOM 2.** Phylogenetic Analysis of Euantiarchi (modified from Wang & Zhu 2018)

1) Character list
2) Data matrix with 57 morphological characters for **33 taxa of Euantiarcha**
SOM 1. Phylogenetic Analysis of Antiarchi (modified from Wang & Zhu 2018)

1) Character list

Ornamentation, histology and scales

1. Adult ornamentation:
   tubercular (0);
   reticular (1).

2. Adult ornamentation:
   non-ridged (0);
   ridged (1).

3. Ridges on dorsal wall of trunk shield:
   converging (0);
   subparallel (1).

4. Dorsal spongy layer in dermal bone of trunk shield:
   absent (0);
   present (1).

5. Ridged scales:
   absent (0);
   present (1).

Head shield and neurocranium

6. Premedian plate:
   absent (0);
   present (1).

7. Premedian plate:
   short and broad (0);
   long and narrow (1).

8. Anterior margin of premedian plate:
   convex (0);
   slightly concave (1).

9. Unornamented shelf and rostrocaudal groove on premedian plate:
   absent (0);
   present (1).

10. Rostral width/orbital width index of premedian plate:
smaller than 200 (0).
larger than 200 (1).

11. Lateral plate:
   absent (0);
present (1).

12. Lateral plate:
narrow (0);
broad (1).

13. Preorbital depression:
present (0);
absent (1).

14. Preorbital depression:
extending laterally onto lateral plates (0);
   restricted to premedian plate (1).

15. Preorbital recess:
absent (0);
present (1);

16. Preorbital recess:
   restricted to premedian plate (0);
   extending laterally to the lateral plates (1).

17. Orbital opening:
open (0);
   enclosed by skull roof plates (1).

18. Orbital fenestra:
   large (0);
   small (1).

19. Relative position of orbital fenestra (ordered):
   anterior (0);
   slightly anterior (1);
   slightly posterior (2);
   posterior (3).
20. **Nasal opening:**
   at anterolateral corners of rostral plate (0);
   at anterior margin of rostral plate (1).

21. **Postpineal and nuchal plates:**
   long and narrow (0);
   short and broad (1).

22. **Pronounced postpineal thickening:**
   absent (0);
   present (1).

23. **Position of postorbital crista:**
   extending medially to postpineal plate (0);
   extending obliquely to nuchal plate (1).

24. **Nuchal plate:**
   without orbital facets (0).
   with orbital facets (1).

25. **Supraotic thickening of head shield:**
   absent (0);
   present (1).

26. **Median occipital crista of head shield:**
   absent (0);
   present (1).

27. **Posterior process of head shield:**
   absent (0);
   present (1).

28. **Obstantic margin:**
   long (0);
   short (1).

29. **Central sensory canal:**
   present (0);
   absent (1).

30. **Supraorbital canal:**
31. **X-shaped pit-line grooves:**
   - present (0);
   - absent (1).

32. **Branch of infraorbital canal diverging on lateral plate:**
   - present (0);
   - absent (1).

33. **Semicircular pit-line:**
   - absent (0);
   - present (1).

34. **Occipital cross-commissure issued from infraorbital canal:**
   - absent or short (0);
   - long and extending onto nuchal plate (1).

35. **Anterior postorbital process:**
   - behind anterior level of orbital notch (0);
   - extending in front of orbital notch (1).

36. **Anterior postorbital process:**
   - at or behind posterior level of orbital notch (0);
   - in front of posterior level of orbital notch (1).

37. **Cavity for cranio-spinal process:**
   - absent (0);
   - present (1).

38. **Supraoccipital pit of head shield:**
   - absent (0);
   - present (1).

39. **Confluence between anterior and posterior semicircular canals:**
   - midway between orbital notch and transverse nuchal crista or close to orbital notch (0);
   - close to transverse nuchal crista (1).

40. **Endolymphatic duct through head shield:**
   - long tube (0);
short tube (1).

41. **Occipital portion of endocranium**
   long (0);
   short (1).

42. **Submarginal articulation:**
   absent (0);
   present (1).

43. **Postsuborbital plate:**
   present (0);
   absent (1).
The plate was termed as the prelateral plate in Zhu (1996).

44. **Postsuborbital plate:**
   with a long anterior process (0);
   equilateral, triangular in shape (1).

45. **Postsuborbital plate:**
   behind suborbital plate (0);
   above suborbital plate (1).
The suborbital was termed as the mental plate in Zhu (1996).

46. **Suborbital plates of both sides:**
   separated (0);
   meeting in the midline (1).

**Trunk shield**

47. **Shape of trunk shield:**
   low and elongated (0);
   high and short (1).
   Wang & Zhu (2018, Character 47);

48. **Number of median dorsal plates:**
   one (0);
   two (1).

49. **Index** 
   \( r_1 \) between width of anterior margin and maximum width of anterior median dorsal plate (ordered):
   \( r_1>55 \) (0);
   \( 35<=r_1<=55 \) (1);
   \( 15<=r_1<35 \) (2);
The anterior median dorsal plate of antiarchs is homologous to the median dorsal plate 1 in *Qilinyu* (Zhu et al. 2016) and the extrascapular plate in *Entelognathus* (Zhu et al. 2013), and some arthrodires (Goujet 1973). It is absent in *Kujdanowiaspis*.

50. **Index (r₂) between anterior and posterior divisions of anterior median dorsal plate (ordered):**
   - r₂<300 (0);
   - 300=<r₂=<500 (1);
   - >500 (2).

51. **Tergal angle of anterior median dorsal plate:**
   - centrally or posteriorly placed (0);
   - anteriorly placed (1).

52. **Dorsal spine of anterior median dorsal plate:**
   - absent (0);
   - present (1).

53. **Anterior median dorsal plate:**
   - completely overlapping anterior dorsolateral plate (0);
   - partly overlapping anterior dorsolateral plate (1).

54. **Anterior median dorsal plate:**
   - underlapping or partly overlapping posterior dorsolateral (or mixilaterial) plate (0);
   - completely overlapping posterior dorsolateral (or mixilaterial) plate (1).

55. **Anterior median dorsal plate:**
   - partly or completely overlapping posterior dorsolateral (or mixilaterial) plate (0);
   - underlapping posterior dorsolateral (or mixilaterial) plate (1).

56. **Anterior ventral process and pit on anterior median dorsal plate:**
   - present (0);
   - absent (1).

57. **Lateral process of posterior median dorsal plate:**
   - conspicuous (0);
   - reduced (1).

58. **Crista transversalis interna posterior of trunk shield:**
   - lying laterally to posterior ventral pit and process of posterior median dorsal plate (0).
   - lying behind posterior ventral pit and process of posterior median dorsal plate (1).
59. **Posterior ventral pit and process of posterior median dorsal plate:**
on crista transversalis interna posterior (0);
posteriorly migrated behind crista transversalis interna posterior (1).

60. **Crista transversalis interna posterior of trunk shield:**
lying laterally to posterior ventral process and pit (0).
turning anteriorly and in front of posterior ventral process and pit (1).

61. **Anterior lateral plate:**
present (0);
absent (1).

62. **Chang’s apparatus:**
absent (0);
present (1).

63. **Ventrolateral fossa of trunk shield:**
absent (0);
present (1).

64. **Posterior dorsolateral and posterior lateral plates:**
independent (0);
fused to form a mixilateral plate (1).

65. **Posterior ventrolateral and posterior lateral plates:**
independent (0);
fused to form (or replaced by) a single plate (1).

66. **Semilunar plate:**
paired (0);
unpaired (1).

67. **Large rectangular aperture on ventral wall of trunk shield:**
absent (0);
present (1).

68. **Spinal plate:**
present (0);
absent (1).
69. Postbranchial lamina:  
- external and upright (0);  
- internal and horizontal (1).  

70. Pectoral fin:  
- scale-covered (0);  
- modified into a slender appendage covered with small dermal plates (1).  

71. Number of plates encircling pectoral fenestra:  
- two or more (0);  
- one (1).  

72. Brachial process:  
- absent (0);  
- present (1);  

73. Brachial process:  
- simple (0);  
- helmet-shaped (1);  

74. Axillary foramen:  
- small (0);  
- large (1).  

75. Pectoral appendage:  
- unjointed (0);  
- jointed (1).  

76. Dorsal central plate 1 and dorsal central plate 2 of pectoral appendage:  
- in contact (0);  
- separated (1).  

77. Pectoral appendage:  
- short (0);  
- elongated (1).  

78. Lateral marginal plate 2 relative to trunk shield:  
- short (0);  
- elongated (1).  
79. Number of lateral marginal plates of distal segment:
   - three (0);
   - two (1).

80. PDL overlaps ADL in dorsal part and is overlapped in ventral part:
   - absent (0);
   - present (1).
   New character, based on character mentioned by Young (2010).

2) Data matrix with 80 morphological characters for 47 taxa

<table>
<thead>
<tr>
<th>Character</th>
<th>Kujdanowiaspis</th>
<th>Romundina</th>
<th>Chuchinolepis</th>
<th>Vanchienolepis</th>
<th>Zhanjilepis</th>
<th>Heteroyunnanolepis</th>
<th>Yunnanolepis</th>
<th>Mizia</th>
<th>Phymolepis</th>
<th>Parayunnanolepis</th>
<th>Minicrania</th>
<th>Liujiangolepis</th>
<th>Xichonolepis</th>
<th>Dayaoshania</th>
<th>Grenfellaspis</th>
<th>Sinolepis</th>
<th>Wudinolepis</th>
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</table>
SOM 2. Phylogenetic Analysis of Euantiarchi (modified from Wang & Zhu 2018)

1) Character list

Ornamentation, histology and scales

1. **Adult ornamentation:**
   - tubercular (0);
   - reticular (1).

2. **Adult ornamentation:**
   - non-ridged (0);
   - ridged (1).

3. **Ridges on dorsal wall of trunk shield:**
   - converging (0);
   - subparallel (1).

4. **Dorsal spongy layer in dermal bone of trunk shield:**
   - absent (0);
   - present (1).

5. **Ridged scales:**
   - absent (0);
   - present (1).

Head shield and neurocranium

6. **Premedian plate:**
   - short and broad (0);
   - long and narrow (1).

7. **Anterior margin of premedian plate:**
   - convex (0);
   - slightly concave (1).
8. **Unornamented shelf and rostrocaudal groove on premedian plate:**
   - absent (0);
   - present (1).

9. **Rostral width/orbital width index of premedian plate:**
   - smaller than 200 (0).
   - larger than 200 (1).

10. **Lateral plate:**
    - narrow (0);
    - broad (1).

11. **Preorbital depression:**
    - present (0);
    - absent (1).

12. **Preorbital recess:**
    - absent (0);
    - present (1);

13. **Preorbital recess:**
    - restricted to premedian plate (0);
    - extending laterally to the lateral plates (1).

14. **Orbital fenestra:**
    - large (0);
    - small (1).

15. **Relative position of orbital fenestra (ordered):**
    - anterior (0);
    - slightly anterior (1);
    - slightly posterior (2);
    - posterior (3).

16. **Nasal opening:**
    - at anterolateral corners of rostral plate (0);
    - at anterior margin of rostral plate (1).

17. **Postpineal and nuchal plates:**
    - long and narrow (0);
    - short and broad (1).
18. Pronounced postpineal thickening:
   absent (0);
   present (1).

19. Position of postorbital crista:
   extending medially to postpineal plate (0);
   extending obliquely to nuchal plate (1).

20. Nuchal plate:
   without orbital facets (0).
      with orbital facets (1).

21. Supraotic thickening of head shield:
   absent (0);
   present (1).

22. Median occipital crista of head shield:
   absent (0);
   present (1).

23. Obstantic margin:
   long (0);
   short (1).

24. Central sensory canal:
   present (0);
   absent (1).

25. X-shaped pit-line grooves:
   present (0);
   absent (1).

26. Branch of infraorbital canal diverging on lateral plate:
   present (0);
   absent (1).

27. Semicircular pit-line:
   absent (0);
   present (1).
28. **Anterior postorbital process:**
   behind anterior level of orbital notch (0);
   extending in front of orbital notch (1).

29. **Anterior postorbital process:**
   at or behind posterior level of orbital notch (0);
   in front of posterior level of orbital notch (1).

30. **Submarginal articulation:**
   absent (0);
   present (1).

31. **Postsuborbital plate:**
   present (0);
   absent (1).
   The plate was termed as the prelateral plate in Zhu (1996).

32. **Postsuborbital plate:**
   behind suborbital plate (0):
   above suborbital plate (1).
   The suborbital was termed as the mental plate in Zhu (1996).

33. **Suborbital plates of both sides:**
   separated (0):
   meeting in the midline (1).

34. **Shape of trunk shield:**
   low and elongated (0);
   high and short (1).
   Wang & Zhu (2018, Character 47);

35. **Index (r_1) between width of anterior margin and maximum width of anterior median dorsal plate (ordered):**
   r_1>55 (0);
   35=<r_1=<55 (1);
   15=<r_1<35 (2);
   <15 (3).

36. **Index (r_2) between anterior and posterior divisions of anterior median dorsal plate (ordered):**
   r_2<300 (0);
   300=<r_2=<500 (1);
37. **Tergal angle of anterior median dorsal plate:**
   - centrally or posteriorly placed (0);
   - anteriorly placed (1).

38. **Dorsal spine of anterior median dorsal plate:**
   - absent (0);
   - present (1).

39. **Dorsal spine of anterior median dorsal and posterior median dorsal plate:**
   - absent (0);
   - present (1).
   New character.

40. **Anterior median dorsal plate:**
   - completely overlapping anterior dorsolateral plate (0);
   - partly overlapping anterior dorsolateral plate (1).

41. **Anterior median dorsal plate:**
   - underlapping or partly overlapping posterior dorsolateral (or mixilateral) plate (0);
   - completely overlapping posterior dorsolateral (or mixilateral) plate (1).

42. **Anterior median dorsal plate:**
   - partly or completely overlapping posterior dorsolateral (or mixilateral) plate (0);
   - underlapping posterior dorsolateral (or mixilateral) plate (1).

43. **Anterior ventral process and pit on anterior median dorsal plate:**
   - present (0);
   - absent (1).

44. **Lateral process of posterior median dorsal plate:**
   - conspicuous (0);
   - reduced (1).

45. **Crista transversalis interna posterior of trunk shield:**
   - lying laterally to posterior ventral pit and process of posterior median dorsal plate (0);
   - lying behind posterior ventral pit and process of posterior median dorsal plate (1).

46. **Posterior ventral pit and process of posterior median dorsal plate:**
   - on crista transversalis interna posterior (0);
   - posteriorly migrated behind crista transversalis interna posterior (1).
47. *Crista transversalis interna posterior of trunk shield*: lying laterally to posterior ventral process and pit (0). turning anteriorly and in front of posterior ventral process and pit (1).

48. *Posterior dorsolateral and posterior lateral plates*: independent (0); fused to form a mixilateral plate (1).

49. *Posterior ventrolateral and posterior lateral plates*: independent (0); fused to form (or replaced by) a single plate (1).

50. *Semilunar plate*: paired (0); unpaired (1).

51. *Axillary foramen*: small (0); large (1).

52. *Pectoral appendage*: unjointed (0); jointed (1).

53. *Dorsal central plate 1 and dorsal central plate 2 of pectoral appendage*: in contact (0); separated (1).

54. *Pectoral appendage*: short (0); elongated (1).

55. *Lateral marginal plate 2 relative to trunk shield*: short (0); elongated (1).

56. *Number of lateral marginal plates of distal segment*: three (0); two (1).
57. PDL overlaps ADL in dorsal part and is overlapped in ventral part:  
   absent (0);  
   present (1).  
   New character, based on character mentioned by Young (2010).

2) Data matrix with 57 morphological characters for 33 taxa of Euantiarcha  
? = unavailable character; - = logical impossibility. Data are interleaved to facilitate copying and nesting into Nexus format.  

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