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SUPPLEMENTARY ONLINE MATERIAL FOR

A phylogenetic analysis of the Cyathaspididae

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Supplementary Online Material

SOM 1. Cyathaspididae character and transition state list with references.

SOM 2. Cyathaspididae data matrix of the 29 taxa and 35 characters used to produce the two most parsimonious trees of Figure 3 (Elliott et al. 2021).

SOM 3. Cyathaspididae 30t 35c to be run in PAUP*.

SOM 4. Cyathaspididae 30t 35c scripted to be run in TNT.

The supplementary data files are also available on dryad.org associated with this article.

SOM 1. Cyathaspidae character and transition state list

Dorsal plate

1. Maxillary brim ornament: (0) narrow with ridges parallel to the anterior margin; (1) broad with ridges parallel to the anterior margin; (2) ridges oriented antero-posteriorly; (3) narrow and unornamented. The rostral margin is folded ventrally to form this structure. It is present in some form in all cyathaspids in which this area has been prepared and exposed. Adapted from Lundgren and Blom (2013) Ch. 9.

2. Median rostral lobe or process: (0) present; (1) absent. A posteriorly directed ventral process of the rostrum. Conspicuous in *Torpedaspis elongata* (Broad and Dineley 1973); absent in *Ptomaspis* (Denison 1964) and the Boothiaspidinae (Elliott 2016). Adapted from Lundgren and Blom (2013) Ch. 10.

3. Preorbital process: (0) present and strongly developed; (1) present and weakly developed; (2) fused with sub orbital plate. Ventrally directed process of the dorsal shield anterior to the eye. Strongly developed in *Vernonaspis*, (Denison 1964); fused to the suborbital plate to form an enclosed orbit in *Alainaspis platyrhina* (Elliott and Dineley 1985). Adapted from Lundgren and Blom (2013) Ch. 11.

4. Lateral margin of dorsal plate constricted in front of orbits: (0) absent; (1) present. This feature is characteristic of *Poraspis* (Denison 1964).

5. Preorbital suture: (0) absent; (1) present. A notch in the ventral edge of the preorbital process present in *Alainaspis* and *Boothiaspis* (Broad 1973; Elliott and Dineley 1985).

Adapted from Randle and Sansom (2017) Ch. 46.

6. Anterior margin of the rostrum: (0) bluntly rounded; (1) tapering; (2) rounded; (3) rounded with medial lobe. Adapted from Pernègre and Goujet (2007) Ch. 35; Pernègre and Elliott (2008) Ch. 30.

7. Rostral ridge pattern: (0) transverse; (1) radiating; (2) longitudinal; (3) irregular whorls. Superficial dentine ridges are usually arranged in regular transverse or radiating patterns on the rostrum but in *Faberaspis* (Elliott et al. 2018), *Homalaspidella* (Denison 1964) and *Phyllonaspis* (Elliott 2016) the ridges are longitudinal. In *Torpedaspis* (Broad and Dineley 1973) the pattern consists of irregular whorls. Adapted from Lundgren and Blom (2013) Chs. 51, 52.

8. Postrostral field: (0) present; (1) absent. The anterior part of the central epitegum may show ornamentation differing in orientation from the main part of the epitegum in a triangular area delimited by the supraorbital sensory canals. Present in *Archegonaspis*, *Asketaspis*, *Ptomaspis* and *Tolypelepis*. Adapted from Lundgren and Blom (2013) Ch. 48.

9. Pineal macula: (0) present; (1) pineal area indistinct or indicated by short concentric ridges; (2) absent. The macula is a distinct, relatively large denticle situated above the pineal organ. It is well developed in *Anglaspis*, indistinct in *Americaspis* and absent in *Pionaspis*.

10. Rostral epitegum: (0) present; (1) absent. Not present in Americaspidae, Boothiaspididae and Poraspidae. Adapted from Lundgren and Blom (2013) Ch. 24.

11. Lateral epitega: (0) divided into orbital and posterolateral areas; (1) present; (2) absent.

The lateral epitega are divided in orbital and posterolateral areas in *Asketaspis* and *Tolypelepis*.

12. Interepitegal band of tubercles: (0) present; (1) absent. Contingent upon the presence of rostral epitegum (Ch. 10) and lateral epitega (Ch. 11). Adapted from Lundgren and Blom (2013) Ch. 38.

13. Lateral epitega reach the posterior margin of the dorsal plate: (0) present and do reach border; (1) present and do not reach the border. Contingent upon the presence of lateral epitega (Character 11). The Anglaspidae and *Asketaspis* have lateral epitega that reach the posterior margin.

14. Lateral brim: (0) absent; (1) present. A narrow, laterally extended lamina present in *Liliaspis*, *Paraliliaspis* and the Boothiaspidinae. Adapted from Lundgren and Blom (2013) Ch. 14.

15. Lateral margins of the dorsal plate: (0) convex and widest posteriorly; (1) convex and widest medially; (2) concave medially. Most cyathaspids are convex but *Faberaspis*, *Homalaspidella* and *Poraspis* are concave medially.

16. Posterior dorsal median crest: (0) absent; (1) present. Present in *Alainaspis*, *Anglaspis*, *Cyathaspis* and *Paraliliaspis* but absent in most cyathaspids. Adapted from Lundgren and Blom (2013) Ch. 19.

17. Dorsal and ventral plates in contact behind the branchial opening: (0) absent; (1) present.

In *Anglaspis*, *Nahanniaspis* and *Poraspis* the branchial opening is situated posteriorly with no contact between the median dorsal and ventral plates.

18. Dorsal plate postbranchial lobe: (0) absent; (1) present and weakly developed; (2) present and strongly developed. The downward postbranchial flexure of the margin of the dorsal plate. Adapted from Lundgren and Blom (2013) Ch. 20.

19. Posterior margin of the dorsal plate: (0) irregular (scale-like units); (1) transverse; (2) triangular; (3) median lobe with lateral concavities; (4) convex. Adapted from Pernègre and Goujet (2007) Ch. 27; Pernègre and Elliott (2008) Ch. 35.

20. Dorsal plate ornamentation: (0) scale-like units; (1) ridges anteriorly breaking down to scale-like units posteriorly; (2) elongated ridges. Most cyathaspids exhibit elongated ridges. There are some distinctions posteriorly in *Archegonaspis*. Adapted from Lundgren and Blom (2013) Chs. 39, 40; Randle and Sansom (2017) Chs. 75, 76.

21. In the central part of the dorsal plate dentine ridges with higher, coarser ridges separated by finer ones: (0) present with short ridge segments; (1) present with continuous ridge segments; (2) absent. Most cyathaspids lack this character. Present in *Cyathaspis* and some archegonaspids. Adapted from Lundgren and Blom (2013) Ch. 46.

22. Needle-shaped ridges (rounded at one end, pointed at the other): (0) present; (1) absent. Distinctive in *Asketaspis*, *Ptomaspis* and *Tolypelepis*. Adapted from Lundgren and Blom (2013) Ch. 55.

23. Dentine ridge crests: (0) convex; (1) angular; (2) flat. Adapted from Randle and Sansom (2017) Ch. 47.

24. Pattern of dentine ridges in the central part of the dorsal plate: (0) longitudinal and short; (1) longitudinal and long; (2) elliptical or concentric; (3) transverse; (4) irregular whorls.

Boothiaspis has transverse ridges in the central part and *Torpedaspis* has irregular whorls in the same area.

25. Ridges form whorls on the lateral margins of the dorsal plate: (0) absent; (1) present. This feature is characteristic of the Boothiaspidinae (Elliott 2016).

Branchial area

26. Position of the branchial opening: (0) at postero-lateral corner of the shield and posteriorly directed; (1) postero-lateral; (2) medial lateral. State 0 is only present in the outgroup, *Athenaegis*. Adapted from Lundgren and Blom (2013) Chs. 29, 30, 31.

27. Branchial plate with a posterior dorsal lobe: (0) absent; (1) present. Contingent upon having a branchial plate, which is true for all cyathaspids but not for the outgroup. Adapted from Lundgren and Blom (2013) Ch. 28.

28. Row of scales between the branchial plate and the ventral plate: (0) absent; (1) present. Present in *Nahanniaspis* and *Dinaspidella* (Dineley and Loeffler 1976). Adapted from Lundgren and Blom (2013) Ch. 4.

Scales and sensory canal system

29. Trunk scales: (0) numerous rows of similar size and shape; (1) dorsolateral and ventrolateral scales of similar size and shape; (2) dorsolateral scales larger than ventrolateral scales. Adapted from Lundgren and Blom (2013) Ch. 32; Randle and Sansom (2017) Ch. 63.

30. Pattern of laterosensory canals: (0) short interrupted lengths; (1) continuous network; (2) anastomosing system. Although *Dikenaspis* and *Irregulareaspis* have an anastomosing system *Dikenaspis* is not considered to be part of the Irregulareaspidinae (Dineley and Loeffler 1976). Adapted from Lundgren and Blom (2013) Ch. 61; Randle and Sansom (2017) Ch. 84.

31. Connection between supraorbital canal and infraorbital canal (transverse supraorbital commissure: (0) absent; (1) present. Adapted from Lundgren and Blom (2013) Ch. 59; Randle and Sansom (2017) Ch. 85.

32. Dorsal transverse commissures: (0) three; (1) four.

Ventral plate

33. Lateral margins of the ventral plate: (0) slightly convex; (1) straight; (2) strongly convex. Straight margins seen in *Boothiaspis*, *Dinaspidella* and *Nahanniaspis*. *Phyllonaspis* has strongly convex lateral margins (Elliott 2016).

34. Ridge pattern of the ventral plate: (0) longitudinal; (1) longitudinal becoming transverse anteriorly; (2) elliptical; (3) irregular whorls. Elliptical ridge patterns evident in *Cyathaspis*, *Capitaspis* and *Dikenaspis* (Dineley and Loeffler 1976). Only *Irregulareaspis* has irregular whorls on the ventral plate.

35. Posterior margin of the ventral plate: (0) transverse; (1) blunt median point; (2) triangular.

All Boothiaspidinae, Irregulareaspidinae and Poraspidinae show a blunt median point.

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Cyathaspididae Data									
Elliott et al. 2020									
	1	2	3	4	5	6	7	8	9
State 0	Narrow with ridges parallel to anterior margin	Absent	Present and strongly developed	Absent	Absent	Bluntly rounded	Transverse	Present	Present
State 1	Broad with ridges parallel to anterior margin	Present	Present and weakly developed	Present	Present	Tapering	Radiating	Absent	Pineal area indistinct or indicated by short concentric ridges
State 2	Ridges oriented antero-posteriorly		Fused with suborbital plate			Rounded	Longitudinal		Absent
State 3	Narrow and unornamented					Rounded with medial lobe	Irregular whorls		
State 4									
	Maxillary brim ornament	Median rostral lobe or process	Preorbital process	Lateral margin of dorsal plate constricted in front of orbits	Preorbital notch	Anterior margin of the rostrum	Rostral ridge pattern	Postrostral field	Pineal macula
<i>Athenaegis chattertoni</i>	0	0	0	0	0	0	0	0	0
<i>Alainaspis platyrhina</i>	3	0	2	0	1	0	1	1	2
<i>Americaspis americana</i>	1	0	1	0	0	2	1	1	1
<i>Anglaspis heintzi</i>	1	?	1	0	0	0	1	1	0
<i>Archegonaspis integra</i>	?	1	0	0	0	0	0	0	1
<i>Archegonaspis lindstromi</i>	?	1	0	0	0	0	0	0	1
<i>Asketaspis interstincta</i>	1	?	0	0	0	2	0	0	0
<i>Boothiaspis ovata</i>	?	1	1	0	1	2	0	1	?
<i>Capitaspis giblingi</i>	?	0	0	0	0	2	0	1	1
<i>Cyathaspis banksi</i>	?	?	?	0	0	1	0	1	2
<i>Dikenaspis yukonensis</i>	?	?	0	0	0	3	0	1	0
<i>Dinaspidella elizabethae</i>	0	1	0	0	?	2	0	1	1
<i>Faberaspis elgae</i>	?	?	1	0	0	2	2	1	0
<i>Homalaspidella borealis</i>	?	1	1	0	0	2	2	1	0
<i>Homalaspidella nitida</i>	?	1	1	0	0	2	2	1	0
<i>Irregularaspis hoeli</i>	?	?	1	0	0	2	0	1	1
<i>Liliaspis philippovae</i>	1	1	0	0	0	0	1	1	0
<i>Nahanniaspis mackenziei</i>	0	1	1	0	0	2	0	1	2
<i>Paraliliaspis egregia</i>	?	0	0	0	0	0	1	1	1
<i>Phyllonaspis laevis</i>	3	1	0	0	0	2	2	1	1
<i>Phyllonaspis serratus</i>	3	1	0	0	0	2	2	1	1
<i>Pionaspis acuticostata</i>	?	1	0	0	0	2	0	1	2
<i>Pionaspis amplissima</i>	?	?	0	0	0	2	0	1	2
<i>Poraspis polaris</i>	1	1	0	1	0	2	1	1	0
<i>Poraspis sericea</i>	1	1	0	1	0	2	1	1	0
<i>Ptomaspis canadensis</i>	?	1	1	0	0	2	0	0	0
<i>Tolypelepis undulata</i>	?	0	1	0	0	2	0	0	0
<i>Torpedaspis elongata</i>	2	0	0	0	0	1	3	1	0
<i>Vernonaspis sekwiaie</i>	?	0	0	0	0	1	0	1	0
<i>Vernonaspis tortucostata</i>	?	?	?	0	?	2	0	1	1

Cyathaspididae Data										
Elliott et al. 2020										
	10	11	12	13	14	15	16	17	18	19
State 0	Present	Divided into orbital and postero-lateral areas	Present	Present and do reach the border	Absent	Convex and widest posteriorly	Absent	Absent	Absent	Irregular (scale-like units)
State 1	Absent	Present	Absent	Present and do not reach the border	Present	Convex and widest medially	Present	Present	Present and weakly developed	Transverse
State 2		Absent				Concave medially			Present and strongly developed	Triangular
State 3										Median lobe with lateral concavities
State 4										Convex
	Rostral epitegum	Lateral epitega	Interepigeal band of tubercles	Lateral epitega reach posterior margin of dorsal plate	Lateral brim	Lateral margins of dorsal plate	Posterior dorsal median crest	Dorsal and ventral plates in contact behind the branchial opening	Dorsal plate postbranchial lobe	Posterior margin of the dorsal plate
<i>Athenaegis chattertoni</i>	0	0	0	0	0	0	0	0	0	0
<i>Alainaspis platyrhina</i>	1	2	-	-	1	0	1	1	2	3
<i>Americaspis americana</i>	1	1	1	1	0	1	0	1	?	3
<i>Anglaspis heintzi</i>	0	1	1	0	0	1	1	0	1	2
<i>Archegonaspis integra</i>	0	1	0	1	0	1	0	?	1	1
<i>Archegonaspis lindstromi</i>	0	1	0	1	0	1	0	?	1	3
<i>Asketaspis interstincta</i>	0	0	0	0	0	1	0	?	2	0
<i>Boothiaspis ovata</i>	?	2	-	-	1	1	0	1	2	1
<i>Capitaspis giblingi</i>	0	1	1	?	0	1	?	?	?	?
<i>Cyathaspis banksi</i>	0	1	1	1	0	1	1	?	?	1
<i>Dikenaspis yukonensis</i>	0	1	1	1	0	1	0	1	?	?
<i>Dinaspis elizabethae</i>	1	2	-	-	0	0	0	1	2	3
<i>Faberaspis elgae</i>	1	2	-	-	0	2	0	?	2	?
<i>Homalaspis borealis</i>	1	2	-	-	0	2	0	1	1	4
<i>Homalaspis nitida</i>	1	2	-	-	0	2	0	?	1	3
<i>Irregulareaspis hoeli</i>	1	2	-	-	0	1	0	1	?	3
<i>Liliaspis philippovae</i>	1	1	1	0	1	1	0	?	?	3
<i>Nahanniaspis mackenziei</i>	1	2	-	-	0	0	0	0	0	2
<i>Paraliliaspis egregia</i>	1	1	1	0	1	1	1	?	?	3
<i>Phyllonaspis laevis</i>	1	2	-	-	1	1	0	1	1	3
<i>Phyllonaspis serratus</i>	1	2	-	-	1	1	0	1	1	3
<i>Pionaspis acuticostata</i>	0	1	1	1	0	1	0	1	2	4
<i>Pionaspis amplissima</i>	0	1	1	1	0	1	0	1	1	3
<i>Poraspis polaris</i>	1	2	-	-	0	2	0	0	1	3
<i>Poraspis sericea</i>	1	2	-	-	0	2	0	0	1	3
<i>Ptomaspis canadensis</i>	0	1	0	1	0	1	0	1	1	0
<i>Tolypelepis undulata</i>	0	0	1	1	0	1	0	?	?	0
<i>Torpedaspis elongata</i>	1	2	-	-	0	1	0	1	1	3
<i>Vernonaspis sekwiai</i>	0	1	0	?	0	1	0	1	2	3
<i>Vernonaspis tortucostata</i>	0	1	1	1	0	1	0	1	1	1

Cyathaspididae Data										
Elliott et al. 2020										
	20	21	22	23	24	25	26	27	28	29
State 0	Scale-like units	Present with short ridge segments	Present	Convex	Longitudinal and short	Absent	At postero-lateral corner of the shield and posteriorly directed	Absent	Absent	Numerous rows of similar size and shape
State 1	Ridges anteriorly breaking down to scale-like units posteriorly	Present with continuous ridge segments	Absent	Angular	Longitudinal and long	Present	Postero-lateral	Present	Present	Dorsolateral and ventrolateral scales of similar size and shape
State 2	Elongated ridges	Absent		Flat	Elliptical or concentric		Medial lateral			Dorsolateral scales larger than ventrolateral scales
State 3					Transverse					
State 4					Irregular whorls					
	Dorsal plate ornamentation	In the central part of the dorsal plate, dentine ridges with higher, coarser ridges separated by finer ones	Needle-shaped ridges	Dentine ridge crests	Pattern of dentine ridges in the central part of the dorsal plate	Ridges form whorls on the lateral margins of the dorsal plate	Position of the branchial opening	Branchial plate with a posterior dorsal lobe	Row of scales between the branchial plate and the ventral plate	Trunk scales
<i>Athenaegis chattertoni</i>	0	0	0	0	0	0	0	-	0	0
<i>Alainaspis platyrhina</i>	2	2	1	2	2	1	1	?	0	?
<i>Americaspis americana</i>	2	2	1	0	1	0	1	?	0	?
<i>Anglaspis heintzi</i>	2	2	1	1	1	0	1	0	0	2
<i>Archegonaspis integra</i>	2	1	1	0	1	0	1	?	0	?
<i>Archegonaspis lindstromi</i>	1	2	1	0	1	0	1	?	0	?
<i>Asketaspis interstincta</i>	0	0	0	0	0	0	2	?	?	?
<i>Boothiaspis ovata</i>	2	2	1	2	3	1	2	?	?	?
<i>Capitaspis giblingi</i>	2	2	1	0	1	0	?	?	?	2
<i>Cyathaspis banksi</i>	2	1	1	0	2	0	1	?	0	?
<i>Dikenaspis yukonensis</i>	2	2	1	2	2	0	2	?	0	?
<i>Dinaspidella elizabethae</i>	2	2	1	0	1	0	1	0	1	1
<i>Faberaspis elgae</i>	2	2	1	2	1	0	2	?	?	?
<i>Homalaspidella borealis</i>	2	2	1	2	1	0	1	?	0	1
<i>Homalaspidella nitida</i>	2	2	1	2	1	0	1	?	0	2
<i>Irregularaspis hoeli</i>	2	2	1	0	1	0	1	?	0	1
<i>Liliaspis philippovae</i>	2	2	1	1	1	0	?	?	?	?
<i>Nahanniaspis mackenziei</i>	2	2	1	1	1	0	1	1	1	1
<i>Paraliliaspis egregia</i>	2	2	1	1	1	0	?	?	?	?
<i>Phyllonaspis laevis</i>	2	2	1	2	1	1	1	1	0	2
<i>Phyllonaspis serratus</i>	2	2	1	2	1	1	1	1	0	2
<i>Pionaspis acuticostata</i>	2	2	1	1	1	0	2	?	0	?
<i>Pionaspis amplissima</i>	2	2	1	2	1	0	2	?	0	2
<i>Poraspis polaris</i>	2	2	1	2	1	0	2	1	0	2
<i>Poraspis sericea</i>	2	2	1	2	1	0	2	?	0	?
<i>Ptomaspis canadensis</i>	1	0	0	0	0	0	2	?	?	?
<i>Tolypelepis undulata</i>	0	0	0	0	0	0	?	1	0	2
<i>Torpedaspis elongata</i>	2	2	1	0	4	0	2	0	0	2
<i>Vernonaspis sekwiaie</i>	2	2	1	0	2	0	2	?	?	?
<i>Vernonaspis tortucostata</i>	2	2	1	0	2	0	2	?	?	?

Cyathaspididae Data						
Elliott et al. 2020						
	30	31	32	33	34	35
State 0	Short interrupted lengths	Absent	Three	Slightly convex	Longitudinal	Transverse
State 1	Continuous network	Present	Four	Straight	Longitudinal becoming transverse anteriorly	Blunt median point
State 2	Anastomosing system			Strongly convex	Elliptical	Triangular
State 3					Irregular whorls	
State 4						
	Pattern of laterosensory canals	Connection between supraorbital canal and infraorbital canal (transverse supraorbital commissure)	Dorsal transverse commissures	Lateral margins of the ventral plate	Ridge pattern of the ventral plate	Posterior margin of the ventral plate
<i>Athenaegis chattertoni</i>	?	?	?	0	0	0
<i>Alainaspis platyrhina</i>	?	?	?	0	1	1
<i>Americaspis americana</i>	0	0	1	0	1	1
<i>Anglaspis heintzi</i>	1	1	1	0	1	2
<i>Archegonaspis integra</i>	?	?	?	0	0	0
<i>Archegonaspis lindstromi</i>	?	?	?	0	0	0
<i>Asketaspis interstincta</i>	?	?	?	?	?	?
<i>Boothiaspis ovata</i>	0	?	?	1	0	1
<i>Capitaspis giblingi</i>	?	?	?	0	2	?
<i>Cyathaspis banksi</i>	?	?	?	0	2	0
<i>Dikenaspis yukonensis</i>	2	1	1	0	2	1
<i>Dinaspidella elizabethae</i>	1	1	1	1	1	2
<i>Faberaspis elgae</i>	1	1	1	?	?	?
<i>Homalaspidella borealis</i>	0	1	1	0	1	1
<i>Homalaspidella nitida</i>	1	1	1	?	?	?
<i>Irregulareaspis hoeli</i>	2	1	1	0	3	2
<i>Liliaspis philippovae</i>	1	1	1	?	?	?
<i>Nahanniaspis mackenziei</i>	1	0	1	1	0	2
<i>Paraliliaspis egregia</i>	1	1	1	0	1	2
<i>Phyllonaspis laevis</i>	0	?	?	2	0	1
<i>Phyllonaspis serratus</i>	0	?	?	2	0	1
<i>Pionaspis acuticostata</i>	1	1	0	0	0	?
<i>Pionaspis amplissima</i>	?	?	?	0	1	?
<i>Poraspis polaris</i>	1	1	1	0	1	1
<i>Poraspis sericea</i>	1	1	1	0	1	1
<i>Ptomaspis canadensis</i>	1	0	0	?	?	?
<i>Tolypelepis undulata</i>	0	0	1	0	0	0
<i>Torpedaspis elongata</i>	1	0	1	0	0	1
<i>Vernonaspis sekwiaie</i>	?	?	?	0	1	2
<i>Vernonaspis tortucostata</i>	?	?	?	?	?	?

SOM 3. Cyathaspididae 30t 35c to be run in PAUP*

#NEXUS

[written Thu Nov 19 15:40:19 MST 2020 by Mesquite version 3.51 (build 898) at LindasHTower/192.168.0.4; contact lsl5@nau.edu Lassiter for questions]

BEGIN TAXA;

TITLE Taxa;

DIMENSIONS NTAX=30;

TAXLABELS

Athenaegis_chattertoni Alainaspis_platyrhina Americaspis_americana
Anglaspis_heintzi Archegonaspis_integra Archegonaspis_lindstromi
Asketaspis_interstincta Boothiaspis_ovata Capitaspis_giblingi Cyathaspis_banksi_
Dikenaspis_yukonensis Dinaspidella_elizabethae Faberaspis_elgae
Homalaspidella_borealis Homalaspidella_nitida Irregulareaspis_hoeli
Liliaspis_philippovae Nahanniaspis_mackenziei Paraliliaspis_egregia
Phyllonaspis_laevis Phyllonaspis_serratus Pionaspis_acuticostata
Pionaspis_amplissima Poraspis_polaris Poraspis_sericea Ptomaspis_canadensis
Tolypelepis_undulata Torpedaspis_elongata Vernonaspis_sekwiae
Vernonaspis_tortucostata
;

END;

BEGIN CHARACTERS;

TITLE Character_Matrix;

DIMENSIONS NCHAR=35;

FORMAT DATATYPE = STANDARD GAP = - MISSING = ? SYMBOLS = " 0 1 2 3 4";

CHARSTATELABELS

1 Maxillary_brim_ornament_,
2 Median_rostral_lobe_or_process,
3 Preorbital_process,
4 Lateral_margin_of_dorsal_plate_constricted_in_front_of_orbits,
5 Preorbital_notch,
6 Anterior_margin_of_the_rostrum,
7 Rostral_ridge_pattern,
8 Postrostral_field,
9 Pineal_macula,
10 Rostral_epitegum,
11 Lateral_epitega,
12 Interepitegal_band_of_tubercles,
13 Lateral_epitega_reach_posterior_margin_of_dorsal_plate,
14 Lateral_brim,
15 Lateral_margins_of_dorsal_plate,
16 Posterior_dorsal_median_crest,
17
Dorsal_and_ventral_plates_in_contact_behind_the_branchial_opening,
18 Dorsal_plate_postbranchial_lobe,
19 Posterior_margin_of_the_dorsal_plate,
20 Dorsal_plate_ornamentation,
21 'In the central part of the dorsal plate, dentine ridges with

higher, coarser ridges separated by finer ones',
 22 'Needle-shaped ridges',
 23 Dentine_ridge_crests,
 24
 Pattern_of_dentine_ridges_in_the_central_part_of_the_dorsal_plate,
 25 Ridges_form_whorls_on_the_lateral_margins_of_the_dorsal_plate,
 26 Position_of_the_branchial_opening,
 27 Branchial_plate_with_a_posterior_dorsal_lobe_,
 28
 Row_of_scales_between_the_branchial_plate_and_the_ventral_plate_,
 29 Trunk_scales,
 30 Pattern_of_laterosensory_canals,
 31 'Connection between supraorbital canal and infraorbital canal
 (transverse supraorbital commissure)',
 32 Dorsal_transverse_commissures,
 33 Lateral_margins_of_the_ventral_plate,
 34 Ridge_pattern_of_the_ventral_plate,
 35 Posterior_margin_of_the_ventral_plate ;

MATRIX

Athenaegis_chattertoni	000000000000000000000000000000-00??000
Alainaspis_platyrhina	30201011212--1011232212211?0??011
Americaspis_americana	1010021111110101?32210101?0?001011
Anglaspis_heintzi	1?100011001100110122211101002111012
Archegonaspis_integra	?100000010101010?112110101?0??000
Archegonaspis_lindstromi	?100000010101010?131210101?0??000
Asketaspis_interstincta	1?00020000000010?200000002???????
Boothiaspis_ovata	?1101201??2--1101212212312??0??101
Capitaspis_giblingi	?00002011011?01????221010??2??02?
Cyathaspis_banksi	??0010120111011??12110201?0??020
Dikenaspis_yukonensis	?000301001110101??2212202?0?211021
Dinaspidella_elizabethae	0100?201112--0001232210101011111112
Faberaspis_elgae	?100221012--020?2?2212102??111???
Homalaspidella_borealis	?1100221012--0201142212101?01011011
Homalaspidella_nitida	?1100221012--020?132212101?02111???
Irregulareaspis_hoeli	?100201112--0101?32210101?01211032
Liliaspis_philippovae	1100001101110110??3221110??0111???
Nahanniaspis_mackenziei	01100201212--0000022211101111101102
Paraliliaspis_egregia	?000001111110111??3221110??0111012
Phyllonaspis_laevis	31000221112--11011322121111020??201
Phyllonaspis_serratus	31000221112--11011322121111020??201
Pionaspis_acuticostata	?1000201201110101242211102?0?11000?
Pionaspis_amplissima	?0000201201110101132212102?02??01?
Poraspis_polaris	11010211012--0200132212102102111011
Poraspis_sericea	11010211012--0200132212102?0?111011
Ptomaspis_canadensis	?1100200001010101101000002??100???
Tolypelepis_undulata	?010020000011010?0000000?102001000
Torpedaspis_elongata	20000131012--0101132210402002101001
Vernonaspis_sekwiaae	?00001010010?0101232210202?????012
Vernonaspis_tortuocostata	??0?201101110101112210202???????

;

END; [Characters block]

BEGIN paup;

Log File = '.\Cyathaspididae_ELB2020_PAUP.log' start;

Factory; [Set PAUP* options to factory defaults]

set criterion=parsimony;

set root=outgroup; [Tree viewing options]

set outRoot=paraphyl; [Tree viewing options]

set tOrder=right tCompress; [Tree viewing options]

set increase=auto; [Remove this possible limitation]

Condense collapse=maxBrlen; [PAUP* default: collapse if max length == 0]

Outgroup Athenaegis_chattertoni; [Specifies the first taxon as the outgroup]

[This starts the Parsimony-Heuristic Search]

Hsearch swap=TBR reconLimit=30 addSeq=random nreps=1500 rseed=1234;

[Output the Tree length, Consistency/Retention/Rescaled Consistency]

PScores / tl ci ri rc;

[This shows which tree is the best by Wilcox ranking]

PScores / nonparamTest;

ShowTrees all;

Condense collaps=minBrlen; [Collapse trees as is performed in TNT]

ConTree / grpFreq=no; [Show trees without details SC]

Log stop;

END; [PAUP script]

SOM 4. Cyathaspididae 30t 35c scripted to be run in TNT

xread

35 30

Athenaegis_chattertoni 00000000000000000000000000-00??000
 Alainaspis_platyrhina 30201011212--1011232212211?0??011
 Americaspis_americana 10100211111110101?32210101?0?001011
 Anglaspis_heintzi 1?100011001100110122211101002111012
 Archegonaspis_integra ?1000001010101?112110101?0??000
 Archegonaspis_lindstromi ?1000001010101?131210101?0??000
 Asketaspis_interstincta 1?0002000000010?200000002??????
 Boothiaspis_ovata ?1101201?2--1101212212312??0??101
 Capitaspis_giblingi ?00002011011?01????221010??2??02?
 Cyathaspis_banksi_ ???0010120111011??12110201?0??020
 Dikenaspis_yukonensis ??000301001110101??2212202?0?211021
 Dinaspidella_elizabethae 0100?201112--0001232210101011111112
 Faberaspis_elgae ??100221012--020?2?2212102??111??
 Homalaspidella_borealis ?1100221012--0201142212101?01011011
 Homalaspidella_nitida ?1100221012--020?132212101?02111??
 Irregulareaspis_hoeli ??100201112--0101?32210101?01211032
 Liliaspis_philippovae 1100001101110110??3221110??111??
 Nahanniaspis_mackenziei 01100201212--0000022211101111101102
 Paraliliaspis_egregia ?00001111110111??3221110??111012
 Phyllonaspis_laevis 31000221112--11011322121111020??201
 Phyllonaspis_serratus 31000221112--11011322121111020??201
 Pionaspis_acuticostata ?1000201201110101242211102?0?11000?
 Pionaspis_amplissima ??000201201110101132212102?02??01?
 Poraspis_polaris 11010211012--0200132212102102111011
 Poraspis_sericea 11010211012--0200132212102?0?111011
 Ptomaspis_canadensis ?1100200001010101101000002??100??
 Tolypelepis_undulata ?010020000011010??000000?102001000
 Torpedaspis_elongata 20000131012--0101132210402002101001
 Vernonaspidis_sekwiae ?00001010010?0101232210202?????012
 Vernonaspidis_tortucostata ???0?201101110101112210202?????????
 ;

cnames

{0 Maxillary_brim_ornament_
 {1 Median_rostral_lobe_or_process;
 {2 Preorbital_process;
 {3 Lateral_margin_of_dorsal_plate_constricted_in_front_of_orbits;
 {4 Preorbital_notch;
 {5 Anterior_margin_of_the_rostrum;
 {6 Rostral_ridge_pattern;
 {7 Postrostral_field;
 {8 Pineal_macula;
 {9 Rostral_epitegum;
 {10 Lateral_epitega;
 {11 Interepитеgal_band_of_tubercles;
 {12 Lateral_epitega_reach_posterior_margin_of_dorsal_plate;
 {13 Lateral_brim;
 {14 Lateral_margins_of_dorsal_plate;

```
{15 Posterior_dorsal_median_crest;
{16 Dorsal_and_ventral_plates_in_contact_behind_the_branchial_opening;
{17 Dorsal_plate_postbranchial_lobe;
{18 Posterior_margin_of_the_dorsal_plate;
{19 Dorsal_plate_ornamentation;
{20
In_the_central_part_of_the_dorsal_plate,_dentine_ridges_with_higher,_coarser_ridges
_separated_by_finer_ones;
{21 Needle-shaped_ridges;
{22 Dentine_ridge_crests;
{23 Pattern_of_dentine_ridges_in_the_central_part_of_the_dorsal_plate;
{24 Ridges_form_whorls_on_the_lateral_margins_of_the_dorsal_plate;
{25 Position_of_the_branchial_opening;
{26 Branchial_plate_with_a_posterior_dorsal_lobe_;
{27 Row_of_scales_between_the_branchial_plate_and_the_ventral_plate_;
{28 Trunk_scales;
{29 Pattern_of_laterosensory_canals;
{30
Connection_between_supraorbital_canal_and_infraorbital_canal_(transverse_supraorbit
al_commissure);
{31 Dorsal_transverse_commissures;
{32 Lateral_margins_of_the_ventral_plate;
{33 Ridge_pattern_of_the_ventral_plate;
{34 Posterior_margin_of_the_ventral_plate;
;

proc /;
comments 0
;
```