A new elasmosaurid plesiosaurian from the Early Cretaceous of Russia marks an early attempt at neck elongation

Supplementary information

Supplementary tables

Table S1. Temporal data used to timescale the phylogenetic tree. See also supplementary file "SUPP_ranges.txt".

	FAD	LAD
Yunguisaurus_liae	242	237
Pistosaurus_postcranium	247.2	242
Pistosaurus_skull	247.2	242
Augustasaurus_hagdorni	247.2	242
Bobosaurus_forojuliensis	237	227
Macroplata_tenuiceps	201.3	199.3
Anningasaura_lymense	201.3	199.3
Stratesaurus_taylori	201.3	199.3
Avalonnectes_arturi	201.3	199.3
Eurycleidus_arcuatus	201.3	199.3
Meyerasaurus_victor	182.7	179.3
Maresaurus_coccai	170.3	168.3
Borealonectes_russelli	166.1	163.5
Rhomaleosaurus_megacephalus	201.3	199.3
Archaeonectrus_rostratus	201.3	199.3
Rhomaleosaurus_cramptoni	182.7	174.1
Rhomaleosaurus_zetlandicus	182.7	174.1
Rhomaleosaurus_thorntoni	182.7	174.1
Attenborosaurus_conybeari	199.3	190.8
Plesiosaurus_dolichodeirus	199.3	190.8
Eopleiosaurus_antiquior	201.3	199.3
Eretmosaurus_rugosus	199.3	190.8
Westphaliasaurus_simonsensii	190.8	182.7
Seelyosaurus_guilelmiimperatori	182.7	174.1

Microcleidus_tournemirensis	182.7	174.1
Microcleidus_brachypterygius	182.7	174.1
Microcleidus_homalospondylus	182.7	174.1
Plesiopterys_wildi	182.7	174.1
Cryptoclidus_eurymerus	166.1	163.5
Tricleidus_seeleyi	166.1	163.5
Muraenosaurus_leedsii	166.1	163.5
Kimmerosaurus_langhami	152.1	145
Pantosaurus_striatus	163.5	157.3
Picrocleidus_beloclis	166.1	163.5
Tatenectes_laramiensis	163.5	157.3
Plesiosaurus_mansellii	157.3	145
Colymbosaurus_trochanterius	157.3	145
Djupedallia_engeri	157.3	145
Spitrasaurus_spp	157.3	145
Abyssosaurus_nataliae	132.9	129.4
Umoonasaurus_demoscyllus	125	100.5
Nichollssaura_borealis	113	110.5
Leptocleidus_capensis	139.8	132.9
Leptocleidus_superstes	129.4	125
Hastanectes_valdensis	139.8	132.9
Vectocleidus_pastorum	129.4	125
Gronausaurus_wegneri	145	139.8
Brancasaurus_brancai	145	139.8
Nakonanectes_bradti	72.1	66
Speeton_Clay_Plesiosaurian	132.9	129.4
Wapuskanectes_betsynichollsae	113	107.8
Eromangasaurus_australis	105.5	100.5

Tuarangisaurus_keyesi	86.3	66
Styxosaurus_snowii	86.3	72.1
Styxosaurus_sp.Hydralm	86.3	72.1
Elasmosaurus_platyurus	86.3	72.1
Terminonatator_ponteixensis	86.3	72.1
Libonectes_morgani	93.9	89.8
Kaiwhekea_katiki	72.1	66
Aristonectes_quiriquinensis	72.1	66
Aristonectes_parvidens	83.6	66
Morturneria_seymourensis	72.1	66
Albertonectes_vanderveldei	86.3	72.1
Kawanectes_lafquenianum	86.3	66
Vegasaurus_molyi	72.1	66
Morenosaurus_stocki	72.1	66
Hydrotherosaurus_alexandrae	72.1	66
Aphrosaurus_furlongi	72.1	66
Zarafasaura_oceanis	72.1	66
Futabasaurus_suzukii	86.3	83.6
Callawayasaurus_colombiensis	125	121
MLP_99_XII_1_5	72.1	66
Thalassomedon_haningtoni	100.5	93.9
Alexandronectes_zealandiensis	72.1	66
LACM_2832__	72.1	66
Cardiocorax_mukulu	72.1	66
Lagenanectes_richterae	132.9	129.4
Jucha_squalea	132.9	129.4
Thalassiodracon_hawkinsii	201.3	199.3
Hauffiosaurus_longirostris	182.7	174.1
Hauffiosaurus_tomistomimus	182.7	174.1

Hauffiosaurus_zanoni	182.7	174.1
Marmornectes_candrewi	166.1	163.5
Peloneustes_philarchus	166.1	163.5
Simolestes_vorax	166.1	163.5
Pliosaurus_funkei	152.1	145
Pliosaurus_westburyensis	157.3	152.1
Pliosaurus_carpenteri	157.3	152.1
Pliosaurus_brachydeirus	157.3	152.1
Pliosaurus_macromerus	157.3	152.1
Pliosaurus_brachyspondylus	157.3	152.1
Pliosaurus_cf_kevani	157.3	152.1
Pliosaurus_kevani	157.3	152.1
Gallardosaurus_iturraldei	163.5	157.3
Pliosaurus_rossicus	152.1	145
Pliosaurus_irgisensis	152.1	145
Pliosaurus_andrewsi	166.1	163.5
Liopleurodon_ferox	166.1	163.5
Kronosaurus_queenslandicus	121	100.5
Polyptychodon_sp	100.5	93.9
Megacephalosaurus_eulerti	93.9	89.8
Brachauchenius_lucasi	93.9	89.8
Brachauchenius_MNA	100.5	93.9
QM_F51291	105.5	100.5
Stenorhynchosaurus_munozi	129.4	125
Anguanax_zignoi	163.5	157.3
Makhaira_rossica	132.9	129.4
Luskhan_itilensis	132.9	129.4
Edgarosaurus_muddi	105.5	100.5

Plesiopleurodon_wellesi	100.5	93.9
Richmond_pliosaur	105.5	100.5
Palmulasaurus_quadratus	93.9	89.8
Pahasapasaurus_haasi	99.6	93.9
Polycotylus_latipinnis	89.8	83.6
Thililua_longicollis	93.9	89.8
Trinacromerum_bentonianum	100.5	89.8
Dolichorhynchops_osborni	83.6	80
Dolichorhynchops_bonneri	83.6	80
Eopolycotylus_rankini	93.9	89.8
Dolichorhynchops_tropicensis	93.9	89.8
Georgiasaurus_penzensis	86.3	83.6
Dolichorhynchops_ROM_29010	86.3	72.1
Dolichorhynchops_herschelensis	76.1	66
Sulcusuchus_erraini	76.1	66
Mauriciosaurus_fernandezi	93.9	89.8
Acostasaurus_pavachoquensis	129.4	125
Pliosaurus_patagonicus	152.1	145
Pliosaurus_almanzaensis	152.1	145
Sachicasaurus_vitae	129.4	125
Kronosaurus_boyacensis	121	113

Table S2. Bodyplan from Soul & Benson (2017) focussing on long necked plesiosaurians (i.e. with Triassic sauropterygians, thalassophoneans, rhomaleaosaurids, and polycotylids removed). The contribution column ("contrib") indicates the average length of cervical centra, obtained by dividing the neck length by the number of cervical centra. See Soul &

Benson (2017) and references therein for the data source. See also supplementary file "SUPP_S&B2017_long_necked.csv".

	Length_including_head	Neck_length_not_including_head	Trunk_length	Cervical	Dorsal	contrib
Albertonectes_vanderveldi_20070110001	1120	700	188	76	18	9.21052631578947
Archaeonectrus_rostratus_38525	367	90	99	24	20	3.75
Attenborosaurus_conybeari_R1339	NA	181	NA	38	21	4.76315789473684
Avalonnectes_arturi_14550	NA	69	54.5	25	19	2.76
Brancasaurus_brancai_A3B4	326	138	88.5	37	22	3.72972972972973
Callawayasaurus_colombiensis_38349	NA	NA	NA	56	25	NA
Colymbosaurus_trochanterius_31787	NA	200	153	41	21	4.8780487804878
Cryptocleidus_eurymerus_3183	372	112	134	32	25	3.5
Cryptoclidus_eurymerus_R2860	NA	104	NA	32	25	3.25
Elasmosaurus_platyurus_10081	1130	667	214	71	23	9.394366197183 1
Eoplesiosaurus_antiquior_8348	NA	135	78	38	NA	3.55263157894737
Hauffiosaurus_longirostris_1033	483	178	203	33	25	5.39393939393939
Hauffiosaurus_tomistomimus_LL_8004	445	152	127	34	21	4.47058823529412
Hauffiosaurus_zanoni_uncatalogued	350	93	98	30	NA	3.1
Hydralmosaurus_serpentius_5835	1130	NA	NA	63	19	NA

Hydrotherosaurus_alexandrae_33912	806	471	140	60	19	7.85
Kaiwhekea_katiki_12649	NA	NA	195	53	23	NA
Libonectes_atlasense_3978	720	400	135	53	21	7.54716981132075
Macroplata_tenuiceps_R5488	465	115	144	27	25	4.25925925925926
Microcleidus_brachypterygius_51143	NA	142	71	36	18	3.94444444444444
Microcleidus_brachypterygius_51141	203	85	NA	37	22	2.2972972972973
Microcleidus_homalospondylus_LL_7135	NA	251	145	40	24	6.275
Microcleidus_homalospondylus_36184	NA	210	NA	40	22	5.25
Microcleidus_indet_51945	NA	136.5	72.5	NA	20	NA
Microcleidus_tournemirensis_J_T_86-100	390	186	82.5	43	19	4.32558139534884
Muraenosaurus_leedsii_R2421	NA	NA	NA	44	22	NA
Muraenosaurus_leedsii_R2863	NA	195	NA	41	26	4.75609756097561
Nichollssaura_borealis_9412201	256	69	92.5	24	24	2.875
Picrocleidus_sp_G181996	NA	170.5	88	44	17	3.875
Plesiopterys_wildi_16812	242.5	88.5	63.5	40	23	2.2125
Plesiosaurus_brachypterygius_3185	299	115	NA	33	NA	3.48484848484848
Plesiosaurus_dolichodeirus_22656	NA	115	NA	41	21	2.80487804878049
Seelyosaurus_guilelmiimperatoris_51015	358	126	94.5	33	21	3.81818181818182
Styxosaurus_snowii_451	NA	600	234.5	62	22	9.67741935483871

Westphaliasaurus_simonsensii_P58091	399	138	NA	23	21	6

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Supplementary figures

Figure S 1. Strict consensus of the most parsimonious trees arising from our implied weight cladistic analysis.

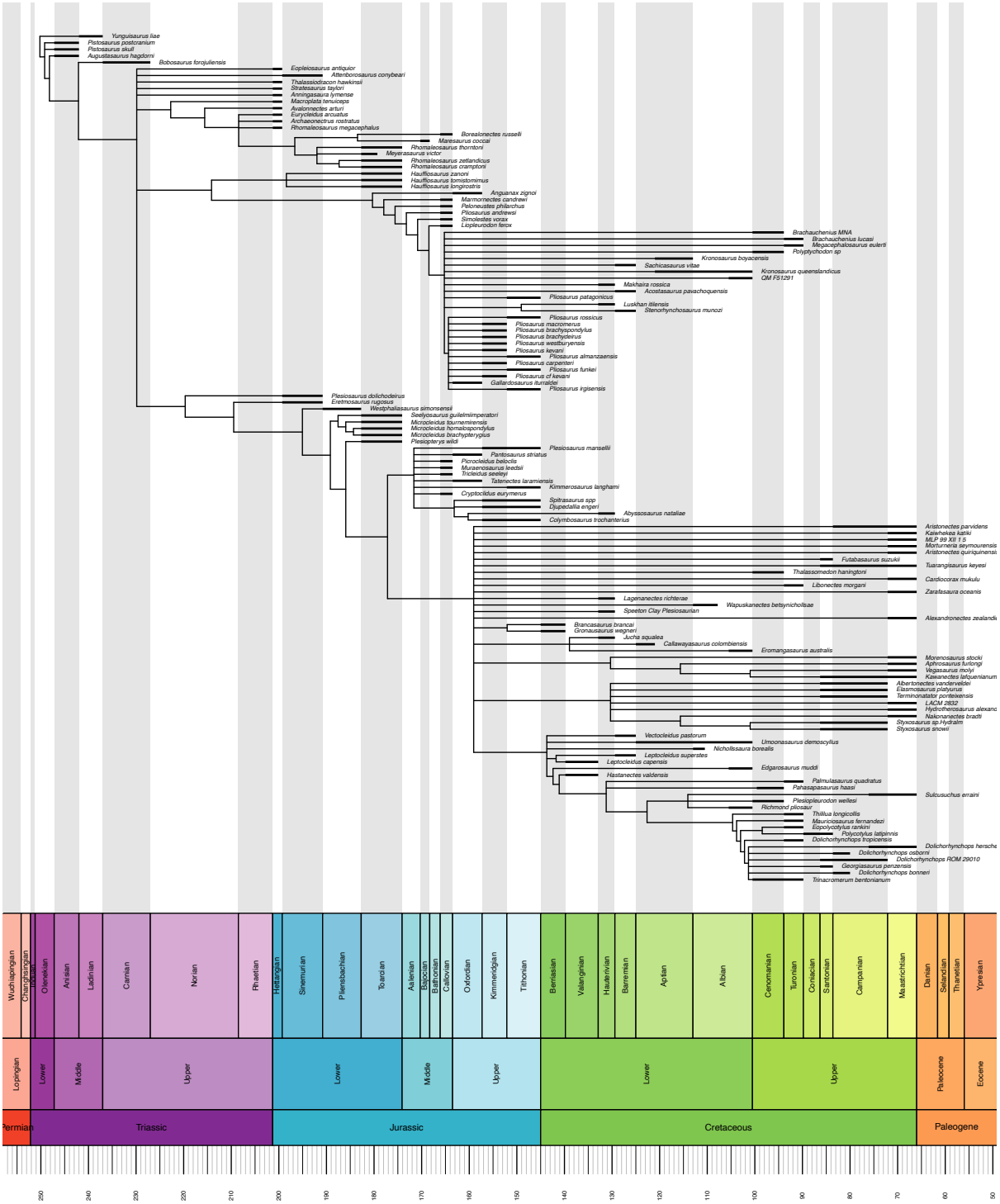

Figure S 2. Strict consensus of the most parsimonious trees arising from our equal weight cladistic analysis.

Figure S 3. Clade support by symmetric resampling, implied weighting analysis.

Figure S 4. Clade support by symmetric resampling, equal weighting analysis.

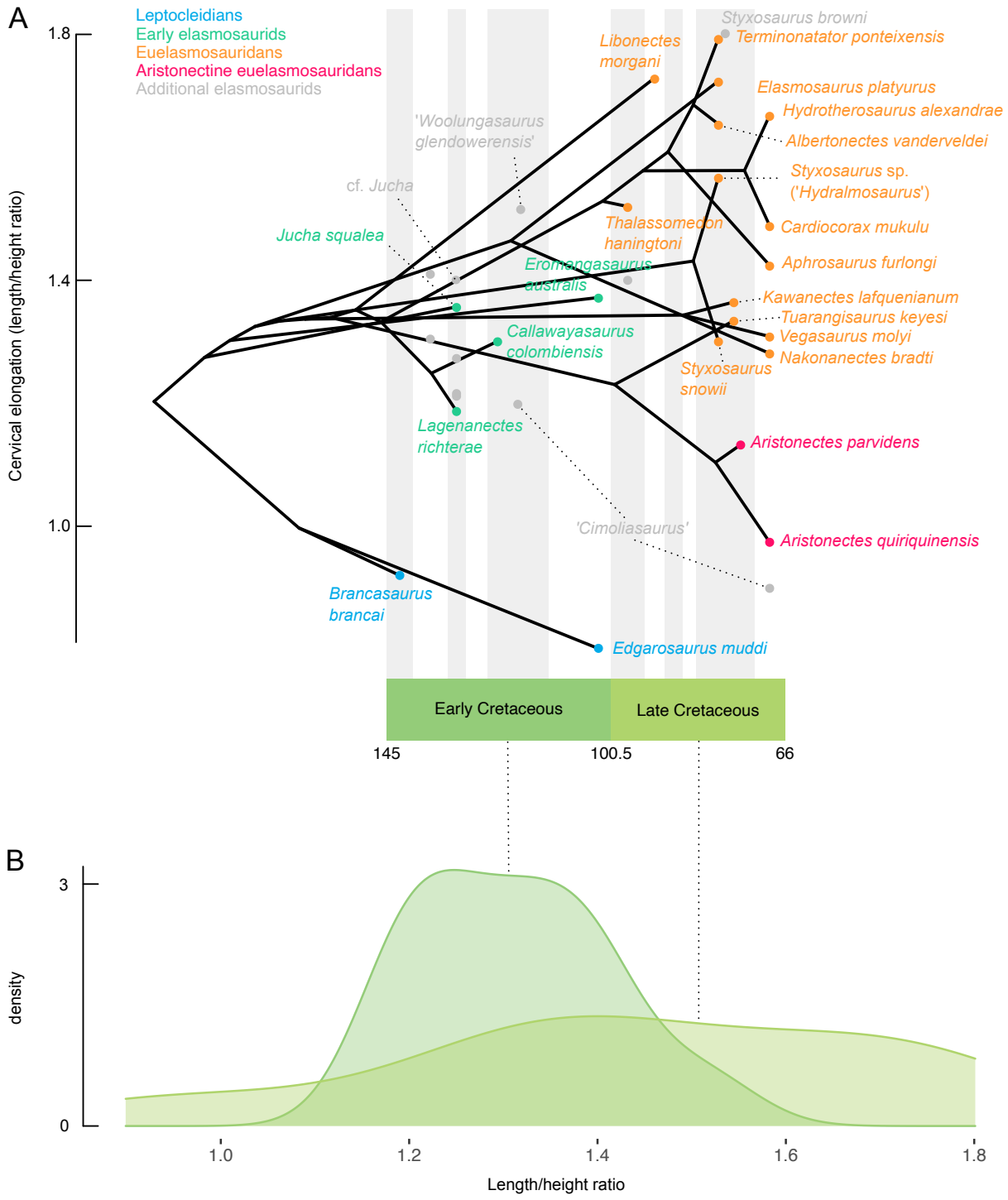

Figure S 5. Patterns of vertebral elongation in cervical centra in elasmosaurids. A: phenogram using the relatively longest centra of the neck, regardless of its position; additional elasmosaurids not included in the phylogeny have been mapped as well (grey dots). B: density distribution of cervical elongation values for the Early and Late Cretaceous.

41 ## References

42 Soul LC, Benson RBJ. 2017. Developmental mechanisms of macroevolutionary change in
43 the tetrapod axis: A case study of Sauropterygia. *Evolution* 71: 1164–1177.

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