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SUPPLEMENTAL CONTENT

Allometric analysis sheds light on the systematics and ontogeny of anurognathid pterosaurs

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# SUPPLEMENTAL METHODS

## R Code to Calculate for Allometric Correlation

############### Bivariate allometric analysis ##############

rm(list=ls())

library(smatr)

library(dplyr)

library(purrr)

# *Copy and paste a set of log-transformed measurements into a txt file using the name x\_y.txt (x as the left column and y as the right), and then load the file into R*

original<-read.table("x\_y.txt")

# *fit SMA to the original dataset*

mod<-sma(V1~V2,data=original, method="SMA")

mod

# *bootstrap with 1000 iterations*

preds <- original %>%

# *create new bootstrapped datasets*

modelr::bootstrap(n = 1000, id = 'boot\_num') %>%

# *fit SMA to every bootstrap dataset*

group\_by(boot\_num) %>%

mutate(., fit = map(strap, ~ sma(V1 ~ V2, data=data.frame(.), method="SMA"))) %>%

ungroup() %>%

# *extract intercept and slope from each fit*

mutate(., intercept = map\_dbl(fit, ~coef(.x)[1]),

slope = map\_dbl(fit, ~coef(.x)[2])) %>%

select(., -fit)

# *one-tailed 95% confidence interval for the slope*

(if(mod[["coef"]][[1]][["coef(SMA)"]][2]>1)

+ quantile(preds$slope,c(0.05,1))

else(quantile(preds$slope,c(0.00,0.95))))

############### PCA allometric analysis with missing data ##############

rm(list=ls())

library(missMDA)

library(boot)

*# Copy and paste the log-transformed measurements into a csv file using the name using the name PCAdata.csv (each skeletal variable as a column; missing values marked as NA), and then load the dataset into R*

originaldata<-read.csv("PCAdata.csv",header=TRUE)

originaldata

*# estimate number of components for imputation*

nc <- estim\_ncpPCA(originaldata, ncp.min=0, ncp.max=5)

nc$ncp

*# imputation to generate a complete dataset*

imputation <- imputePCA(originaldata, ncp=nc$ncp)

*# show the complete dataset*

completedata<-imputation$completeObs

completedata

*# proportion of variance explained by PC1*

pca<-prcomp(completedata)

summary(pca)$importance[2,"PC1"]

*# define a function to calculate the* *allometric scaling coefficient for each skeletal variable*

bootdata = function(data,indices){

a<-data[indices,]

b<-prcomp(a)

c(abs(b$rotation[,1])/(ncol(completedata)^(-0.5)))

}

*#bootstrap with 1000 iterations*

bootresult<-boot(completedata,bootdata,R=1000)

*# allometric scaling coefficient for each skeletal variable*

bootresult$t0

*# one-tailed 95% confidence interval for each allometric scaling coefficient*

for(i in 1:ncol(completedata))

{if(bootresult$t0[i]>1)

{print(names(bootresult$t0[i]))

print(quantile(bootresult$t[,i],c(0.05,1)))}

else

{print(names(bootresult$t0[i]))

print(quantile(bootresult$t[,i],c(0.00,0.95)))}}

## Character List

{0 Skull\_aspect\_ratio,\_length\_relative\_to\_height\_at\_most\_posterior\_point\_preserved\_between\_anterior\_margin\_of\_external\_naris\_or\_nasoantorbital\_fenestra\_and\_jaw\_articulation\_exclusive\_of\_cranial\_crests:\_continuous;

{1 (REVISED from Longrich et al., 2018) Skull,\_length\_to\_squamosal\_relative\_to\_humerus\_length:\_continuous;

{2 Mandble,\_length\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{3 Rostrum,\_length\_to\_external\_naris\_(or\_nasoantorbital\_fenestra)\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{4 External\_naris,\_length\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{5 External\_naris,\_length\_relative\_to\_height:\_continuous;

{6 Antorbital\_fenestra,\_length\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{7 Antorbital\_fenestra,\_length\_relative\_to\_height:\_continuous;

{8 Nasoantorbital\_fenestra,\_length\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{9 Nasoantorbital\_fenestra,\_length\_relative\_to\_height:\_continuous;

{10 Orbit,\_length\_relative\_to\_height:\_continuous;

{11 Supratemporal\_fenestra,\_length\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{12 Subtemporal\_fenestra,\_length\_relative\_to\_width:\_continuous;

{13 Basipterygoid\_processes,\_angle\_divided\_by\_100:\_continuous;

{14 Rostral\_tooth\_row,\_length\_to\_posterior\_margin\_relative\_to\_skull\_length\_to\_squamosal:\_continuous;

{15 Teeth,\_maximum\_number\_divided\_by\_1000:\_continuous;

{16 Mandibular\_symphysis,\_length\_relative\_to\_mandible\_length:\_continuous;

{17 Mandible\_length,\_relative\_to\_ramus\_mid-depth:\_continuous;

{18 Mandibular\_crest,\_length\_relative\_to\_mandible\_length:\_continuous;

{19 Mandibular\_tooth\_row,\_length\_relative\_to\_mandible\_length:\_continuous;

{20 Mid-cervical\_vertebra,\_maximum\_length\_relative\_to\_mid-width:\_continuous;

{21 Mid-cervical\_vertebra,\_maximum\_length\_relative\_to\_dorsal\_vertebra\_length:\_continuous;

{22 Dorsal\_vertebra,\_length\_relative\_to\_maximum\_diameter:\_continuous;

{23 Synsacral\_verebra,\_number:\_continuous;

{24 Caudal\_vertebra,\_length\_relative\_to\_dorsal\_vertebra\_length:\_continuous;

{25 Caudal\_vertebra,\_length\_relative\_to\_diameter:\_continuous;

{26 Scapula,\_length\_relative\_to\_coracoid\_length:\_continuous;

{27 Deep\_coracoid\_flange,\_length\_relative\_to\_coracoid\_length:\_continuous;

{28 Humerus,\_length\_relative\_to\_dorsal\_vertebra\_length:\_continuous;

{29 Humerus,\_deltopectoral\_crest,\_proximodistal\_constriction\_width\_relative\_to\_anterior\_terminus\_proximodistal\_width:\_continuous;

{30 Ulna\_or\_radius,\_length\_relative\_to\_humerus\_length:\_continuous;

{31 Radius,\_diameter\_relative\_to\_ulna\_diameter:\_continuous;

{32 Pteroid,\_length\_relative\_to\_ulna\_length:\_continuous;

{33 Metacarpal\_IV,\_length\_relative\_to\_humerus\_length:\_continuous;

{34 Metacarpal\_IV\_mid-width\_relative\_to\_combined\_ulna\_and\_radius\_mid-width:\_continuous;

{35 Metacarpal\_IV\_proximal\_end,\_dorsoventral\_width\_relative\_to\_mid-width:\_continuous;

{36 Manual\_digit\_IV\_first\_phalanx,\_length\_relative\_to\_humerus\_length:\_continuous;

{37 Manual\_digit\_IV\_second\_phalanx,\_length\_relative\_to\_first\_phalanx\_length:\_continuous;

{38 Manual\_digit\_IV\_third\_wing\_phalanx,\_length\_relative\_to\_first\_phalanx\_length:\_continuous;

{39 Manual\_digit\_IV\_fourth\_wing\_phalanx,\_length\_relative\_to\_first\_phalanx\_length:\_continuous;

{40 Prepubis,\_length\_relative\_to\_width:\_continuous;

{41 Pubis,\_dorsoventral\_depth\_relative\_to\_acetabulum\_anteroposterior\_length:\_continuous;

{42 Ilium\_anterior\_process,\_length\_relative\_to\_posterior\_process\_length:\_continuous;

{43 Femur,\_length\_relative\_to\_humerus\_length:\_continuous;

{44 Tibia,\_length\_relative\_to\_femur\_length:\_continuous;

{45 Fibula,\_free\_length\_relative\_to\_tibia\_length:\_continuous;

{46 Metatarsal\_III,\_length\_relative\_to\_tibia\_length:\_continuous;

{47 (NEW to Longrich et al., 2018; from Wang et al., 2002) First\_phalanx\_of\_pedal\_digit\_V,\_length\_relative\_to\_metatarsal\_III\_length:\_continuous;

{48 (NEW to Longrich et al., 2018; from Wang et al., 2002) Pedal\_digit\_V,\_length\_relative\_to\_pedal\_digit\_III\_length:\_continuous;

{49 (NEW to Longrich et al., 2018; from Wei et al., 2021)

Tail,\_length\_relative\_to\_humerus\_length:\_continuous;

{50 (NEW to Longrich et al., 2018; from Lü et al., 2018) Tibia, length relative to humerus length: continuous;

{51 (NEW to Longrich et al., 2018; from Lü and Hone, 2012)

Tibia, length relative to ulna length: continuous;

{52 Pedal\_digit\_III\_second\_phalanx\_length,\_relative\_to\_mid-width:\_continuous;

{53 Pedal\_digit\_IV\_first\_phalanx,\_length\_relative\_to\_mid-width:\_continuous;

{54 Pedal\_digit\_IV\_second\_phalanx,\_length\_relative\_to\_mid-width:\_continuous;

{55 Pedal\_digit\_IV\_third\_phalanx,\_length\_relative\_to\_mid-width:\_continuous;

{56 Rostrum\_anterior\_margin,\_shape:\_ordered flat\_surface blunt sharp\_tip rostral\_process;

{57 Rostral\_process\_cross-section,\_shape: triangular elliptical;

{58 Rostrum\_anterior\_end,\_orientation:\_ordered upturned straight downturned;

{59 Rostrum,\_anterior\_end,\_lateral\_expansion: absent present;

{60 Jaws,\_anterior\_expansion,\_horizontal\_outline\_shape: elliptical triangular quadrangular;

{61 Rostrum,\_anterior\_occlusal\_margins,\_shape: rounded\_edges sharp\_or\_ridged;

{62 Rostrum,\_middle\_expansion: absent present;

{63 Rostrum,\_posterior\_occlusal\_margins,\_shape: rounded sharp\_or\_ridged;

{64 Rostrum,\_shape: laterally\_attenuated anteroposteriorly\_shortened dorsoventrally\_depressed laterally\_flattened;

{65 Rostrum,\_dorsal\_taper: subparallel attenuated;

{66 Jaws,\_anterior\_end,\_lateral\_taper: attenuated subparallel;

{67 Skull,\_entire\_margin,\_lateral\_shape: \_ordered concave straight attenuated convex;

{68 Skull\_dorsal\_margin,\_curvature\_exclusive\_of\_cranial\_crests:\_ordered convex straight concave;

{69 External\_naris\_dorsal\_and\_ventral\_margins,\_orientation: acute\_angle subparallel;

{70 External\_naris\_(or\_nasoantorbital\_fenestra)\_anterior\_margin,\_position\_relative\_to\_premaxillary\_toothrow: dorsal posterior;

{71 Antorbital\_(or\_nasoantorbital)\_fossa\_on\_jugal: present absent;

{72 Antorbital\_fenestra\_dorsal\_and\_ventral\_margins,\_orientation: subparallel acute\_angle;

{73 Antorbital\_fenestra\_ventral\_margin,\_position\_relative\_to\_external\_naris\_ventral\_margin: same\_level ventral;

{74 External\_naris\_and\_antorbital\_fenestra,\_configuration: separate confluent;

{75 Antorbital\_(or\_nasoantorbital\_fenestra)\_posterior\_margin,\_shape: subangular beveled;

{76 Nasoantorbital\_fenestra\_dorsal\_and\_ventral\_margins,\_orientation: acute\_angle subparallel;

{77 Orbit\_outline,\_shape: subcircular piriform inverted\_triangle;

{78 Orbit,\_dorsal\_position: middle\_of\_the\_skull\_with\_the\_ventral\_margin\_of\_the\_orbit\_below\_the\_middle\_of\_the\_antorbital\_(or\_nasoantorbital)\_fenestra\_and\_the\_dorsal\_margin\_of\_the\_orbit\_above\_the\_dorsal\_margin\_of\_the\_antorbital\_(or\_nasoantorbital)\_fenestra high\_in\_the\_skull\_with\_the\_ventral\_margin\_of\_the\_orbit\_the\_same\_level\_or\_above\_the\_middle\_of\_the\_antorbital\_(or\_nasoantorbital)\_fenestra low\_in\_the\_skull\_with\_the\_entire\_orbit\_lower\_than\_the\_dorsal\_margin\_of\_the\_antorbital\_(or\_nasoantorbital)\_fenestra;

{79 Infratemporal\_fenestra,\_shape: trapezoidal inverted\_triangle upright\_triangle oval elliptical;

{80 Infratemporal\_fenestra,\_position\_relative\_to\_orbit: posterior\_to\_orbit reaches\_under\_orbit;

{81 Infratemporal\_fenestra,\_orientation: subvertical inclined;

{82 Premaxillary\_bar\_(internasal\_process),\_width: wide narrow;

{83 Premaxilla,\_maxillary\_process,\_position:\_ordered contacts\_nasal reaches\_posterior\_half\_of\_external\_naris anterior\_to\_middle\_of\_external\_naris;

{84 Premaxilla,\_posterior\_process,\_posterior\_margin\_position: terminate\_between\_nasals contacts\_frontals;

{85 Premaxillary\_crest: absent present;

{86 Premaxillary\_crest\_anterior\_margin,\_position\_relative\_to\_skull\_anterior\_margin: level posterior;

{87 Premaxillary\_crest\_anterior\_margin,\_orientation:\_ordered inclined\_posteriorly subvertical curving\_anterodorsally;

{88 Premaxillary\_crest,\_shape: tall\_triangle\_decreasing\_in\_height\_posteriorly low\_blade low\_with\_anterior\_humped\_margin comb-like\_with\_straight\_dorsal\_margin semicircular tall\_triangle\_increasing\_in\_height\_posteriorly rectangular;

{89 Premaxillary\_crest\_posterior\_margin,\_position:\_ordered anterior\_to\_external\_naris\_(or\_nasoantorbital\_fenestra)\_anterior\_margin between\_external\_naris\_(or\_nasoantorbital\_fenestra)\_anterior\_margin\_and\_orbit above\_orbit above\_occipital\_region;

{90 Premaxillary\_crest\_dorsal\_spine: absent present;

{91 Premaxillary\_crest,\_thickness: single\_plate two\_plates\_separated\_by\_trabeculae;

{92 Premaxillary\_crest,\_texture: striated smooth branching\_system\_of\_grooves;

{93 Maxilla\_posterior\_end,\_shape: narrow ventrally\_expanded;

{94 Maxilla\_ascending\_process,\_shape: broad tapered slender;

{95 Antorbital\_fossa\_on\_maxilla: present absent;

{96 Maxilla\_and\_nasal\_contact,\_position: maxilla\_contacts\_main\_body\_of\_nasal maxilla\_contacts\_only\_descending\_process\_of\_nasal;

{97 Maxilla,\_premaxillary\_and\_jugal\_processes,\_shape: jugal\_process\_wider both\_narrow premaxillary\_process\_wider both\_wide;

{98 Nasal\_descending\_process: present absent;

{99 Nasal\_descending\_process,\_position: lateral medial;

{100 Nasal\_descending\_process,\_length: short elongate;

{101 Nasal\_descending\_process,\_orientation:\_ordered inclined\_anteriorly ventral inclined\_posteriorly;

{102 Nasal\_process,\_lateral\_pneumatic\_foramen: absent present;

{103 Frontal\_crest: absent present;

{104 Frontal\_crest,\_shape: low\_and\_blunt low\_and\_elongated high\_and\_expanded;

{105 Frontal\_crest\_anterior\_margin,\_position:\_ordered anterior\_to\_orbit above\_orbit posterior\_to\_orbit;

{106 Frontal\_anterior\_margin,\_position\_relative\_to\_preorbital\_bar\_anterior\_margin: anterior posterior;

{107 Lacrimal\_foramen: absent present;

{108 Lacrimal\_descending\_process\_posterior\_margin,\_shape: flat orbital\_process;

{109 Parietal\_crest: absent present;

{110 Parietal\_crest,\_shape: blunt expanded\_into\_rounded\_margin tapered\_into\_triangular\_process elongate\_process;

{111 Squamosal,\_shape: unexpanded rounded expanded;

{112 Squamosal,\_position: above\_base\_of\_lacrimal\_process\_of\_jugal below\_or\_level\_with\_base\_of\_lacrimal\_process\_of\_jugal;

{113 Jugal\_posterior\_process: present absent;

{114 Quadrate,\_inclination\_relative\_to\_ventral\_margin\_of\_skull:\_ordered anteriorly subvertical 120˚\_posteriorly 150˚\_posteriorly;

{115 Mandibular\_articulation,\_position\_relative\_to\_center\_of\_orbit:\_ordered posterior\_to\_orbit posterior\_to\_center\_below\_orbit underneath\_center\_below\_orbit anterior\_to\_center\_below\_orbit anterior\_to\_orbit;

{116 Quadrate,\_shape: wide thin\_and\_cylindrical;

{117 Jugal\_ventral\_margin,\_shape: straight concave;

{118 Jugal\_anterior\_margin,\_position\_relative\_to\_nasoantorbital\_fenestra\_anterior\_margin: posterior same\_level\_or\_anterior;

{119 Jugal\_maxillary\_process: absent present;

{120 Jugal\_postorbital\_process\_and\_lacrimal,\_configuration: do\_not\_contact contact\_to\_form\_lower\_orbital\_bar;

{121 Jugal\_ascending\_and\_postorbital\_processes,\_shape: separated\_by\_distinct\_angle infilled\_by\_concave\_flange;

{122 Jugal\_ascending\_process\_base,\_width: broad narrow;

{123 Jugal\_ascending\_process,\_inclination:\_ordered anterodorsal vertical posterodorsal;

{124 Jugal\_postorbital\_process\_anterior\_margin,\_shape: flat orbital\_process;

{125 Jugal\_posterior\_process,\_orientation: posterior ventral;

{126 Occiput,\_orientation:\_ordered posterior posteroventral ventral;

{127 Basioccipital,\_length\_relative\_to\_width: shorter\_than\_wide longer\_than\_wide;

{128 Basisphenoid\_body,\_length: shorter\_than\_wide at\_least\_longer\_than\_wide;

{129 Elongate\_basipterygoid\_processes: absent present;

{130 Supraoccipital\_crest: absent present;

{131 Supraoccipital,\_pneumatic\_foraminae: absent present;

{132 Palate,\_posterior\_end,\_shape: concave convex;

{133 Palatal\_ridge: absent present;

{134 Palatal\_ridge,\_position: tapering\_anteriorly confined\_posteriorly;

{135 Palatal\_ridge\_shape: narrow\_strip strong\_keel;

{136 Palatines,\_shape: broad\_and\_flat thin\_bars;

{137 Internal\_nares\_and\_maxilla,\_configuration: contact do\_not\_contact;

{138 Pterygoids,\_ventral\_position\_relative\_to\_jaw\_margin: level\_or\_dorsal ventral;

{139 Interpterygoid\_opening,\_length\_relative\_to\_subtemporal\_fenestra\_length: at\_least\_subtemporal\_fenestra shorter\_than\_subtemporal\_fenestra;

{140 Mandible\_articulation\_condyles,\_orientation: parasagittal oblique;

{141 Foramina\_positioned\_in\_a\_row\_along\_the\_lateral\_margin\_of\_the\_jaws: present absent;

{142 Mandible\_anterior\_end,\_orientation:\_ordered upturned straight downturned;

{143 Mandible\_anterior\_margin,\_shape:\_ordered blunt sharp\_tip prow;

{144 Mandible\_anterior\_end,\_shape: compressed\_laterally shortened\_anteroposteriorly depressed\_dorsoventrally;

{145 Mandible,\_anterior\_expansion: absent present;

{146 Mandible\_anterior\_end\_dorsal\_jaw\_margins,\_shape: level eminence;

{147 Mandible\_anterior\_end\_distinct\_eminence,\_height: low high;

{148 Mandibular\_symphysis,\_fusion: unfused fused;

{149 Mandibular\_symphysis,\_orientation: subparallel\_to\_rami oblique\_to\_rami;

{150 Mandible,\_anterior\_end\_lateral\_surfaces,\_texture: flat large\_foramina pitted;

{151 Mandible,\_anterior\_occlusal\_margins,\_shape: rounded\_edges sharp\_or\_ridged;

{152 Mandible,\_distinct\_middle\_expansion: absent present;

{153 Mandible,\_posterior\_occlusal\_margins,\_shape: rounded sharp\_or\_ridged;

{154 Mandibular\_rami\_distinct\_dorsal\_eminence: present absent;

{155 Mandibular\_rami\_dorsal\_eminence,\_shape: rounded pointed;

{156 Mandibular\_sulcus: absent present;

{157 Mandible\_symphysis\_occlusal\_surface\_anterior\_end,\_shape: flat\_or\_concave fossa keel;

{158 Mandible,\_dorsal\_surface,\_parasagittal\_ridges: absent present;

{159 Mandible,\_symphyseal\_cavity: absent present;

{160 Mandibular\_symphyseal\_cavity,\_dorsal\_shelf,\_posterior\_margin\_relative\_to\_ventral\_symphysis\_posterior\_margin: dorsal\_shelf\_posterior\_margin\_extends\_posterior\_to\_ventral\_symphysis\_posterior\_margin ventral\_shelf\_posterior\_margin\_extends\_at\_least\_posterior\_to\_dorsal\_symphysis\_posterior\_margin;

{161 Mandibular\_rami\_dorsal\_margin,\_shape:\_ordered convex straight concave;

{162 Mandibular\_rami,\_orientation: straight\_to\_upturned downcurved;

{163 Retroarticular\_process,\_orientation\_relative\_to\_mandible:\_ordered posteroventral subhorizontal posterodorsal;

{164 Retroarticular\_process,\_shape: triangular subcircular elongate blunt;

{165 Mandible\_ventral\_margin,\_shape: flat keel crest;

{166 Mandibular\_crest,\_shape: blade\_like\_and\_low massive\_and\_deep;

{167 Mandibular\_crest\_anterior\_margin,\_position: posterior\_to\_mandible\_anterior\_margin mandible\_anterior\_margin;

{168 Dentary,\_length: do\_not\_separate\_angular\_and\_surangular separate\_angular\_and\_surangular;

{169 Teeth: present absent;

{170 Teeth,\_spacing\_along\_jaws:\_ordered mesial\_teeth\_spaced\_wider\_apart even\_along\_the\_jaws distal\_teeth\_spaced\_wider\_apart;

{171 Teeth,\_variation\_in\_shape\_along\_tooth\_row: isodont heterodont;

{172 Mesial\_heterodont\_teeth,\_shape: recurved\_triangle slender\_needle recurved\_spike;

{173 Teeth,\_shape: recurved\_triangle bulbous\_triangle slender\_needle recurved\_cone labiolingually\_compressed\_triangle recurved\_spike;

{174 Teeth,\_texture: smooth striated sharp\_mesial\_and\_distal\_keels medial\_carinae;

{175 Teeth,\_maximum\_crown\_height\_relative\_to\_basal\_width: less\_than\_four\_times\_width at\_least\_four\_times\_width;

{176 Teeth,\_lateral\_orientation: vertical inclined\_laterally;

{177 Mesial\_teeth,\_average\_spacing\_between\_successive\_teeth:\_ordered nearly\_touching at\_most\_diameter\_of\_teeth more\_than\_diameter\_of\_teeth;

{178 Cheek\_teeth,\_average\_spacing\_between\_successive\_teeth:\_ordered nearly\_touching at\_most\_diameter\_of\_teeth more\_than\_diameter\_of\_teeth;

{179 Teeth,\_size\_variation: transition\_along\_tooth\_row disparity\_in\_size\_between\_mesial\_and\_distal\_teeth;

{180 Upper\_dentition,\_size\_relative\_to\_lower\_dentition:\_ordered upper\_dentition\_significantly\_larger subequal upper\_dentition\_significantly\_smaller;

{181 Teeth,\_maximum\_curvature: displacement\_of\_curvature\_less\_than\_tooth\_diameter displacement\_of\_curvature\_at\_least\_tooth\_diameter;

{182 Teeth,\_curvature\_orientation: posterior lingual;

{183 Teeth,\_inclination:\_ordered upright mesial\_teeth\_procumbent procumbent;

{184 Cheek\_alveoli,\_shape: set\_in\_grooves low undulating\_occlusal\_margins raised\_rims inflated;

{185 Cheek\_teeth,\_denticles: present absent;

{186 Teeth\_largest\_denticles,\_shape:\_ordered serrations cuspules crenulations low\_cusps tall\_cusps;

{187 Teeth,\_maximum\_denticle\_number:\_ordered more\_than\_50 between\_six\_and\_49 five;

{188 Rostral\_tooth\_row,\_anterior\_end,\_position:\_ordered posterior\_to\_tip\_of\_rostrum tip\_of\_rostrum anterior\_surface\_of\_rostrum;

{189 Maxillary\_teeth,\_position\_of\_largest\_teeth: mesial middle distal;

{190 Fifth\_and\_sixth\_teeth,\_distinctly\_smaller\_than\_fourth\_and\_seventh\_and\_subequal\_in\_size: absent present;

{191 Mandibular\_tooth\_row,\_anterior\_end,\_position: tip\_of\_mandible posterior\_to\_tip\_of\_mandible;

{192 Occlusal\_margin,\_orientation\_with\_respect\_to\_jaw\_margin: parallel dorsally\_reflected;

{193 Atlantoaxis,\_fusion: unfused fused;

{194 Mid-cervical\_vertebra\_neural\_arch\_lateral\_surface,\_pneumatic\_foramen: absent present;

{195 Mid-cervical\_vertebra\_centrum\_lateral\_surface,\_pneumatic\_foramen: absent present;

{196 Cervical\_vertebra\_lateral\_to\_neural\_canal,\_pneumatic\_foramina: absent present;

{197 Mid-cervical\_vertebra\_neural\_spines,\_height:\_ordered tall low extremely\_reduced;

{198 Mid-cervical\_vertebrae\_neural\_spines,\_lateral\_outline\_shape: blade triangular ridge fan;

{199 Mid-cervical\_vertebra,\_postexapophyses: absent present;

{200 Mid-cervical\_vertebra\_neural\_arch\_and\_centrum,\_configuration: distinct confluent;

{201 (REVISED from Longrich et al., 2018) Mid-cervical\_vertebra\_ribs,\_shape:\_ordered elongate reduced absent;

{202 Cervical\_8\_neural\_spine,\_height: tall low;

{203 Cervical\_9,\_shape: similar\_to\_dorsal\_vertebrae similar\_to\_cervicals;

{204 Notarium: absent present;

{205 Anterior\_dorsal\_vertebra\_neural\_spines,\_shape: unfused supraneural\_plate;

{206 Sacral\_ribs,\_configuration: contact\_at\_ilium contact\_medial\_to\_ilium;

{207 Synsacral\_supraneural\_plate: absent present;

{208 Caudal\_vertebra,\_number: more\_than\_15 at\_most\_15;

{209 Caudal\_vertebra\_zygapophyses,\_length:\_ordered short elongate extremely\_elongate;

{210 Caudal\_vertebra\_centrum,\_shape: single duplex;

{211 Scapulocoracoid,\_orientation\_relative\_to\_vertebral\_column: subparallel rotated\_laterally;

{212 Scapula\_proximal\_end,\_shape: elongate\_and\_compressed suboval\_and\_expanded;

{213 Scapula,\_shape: elongate\_process stout\_with\_constricted\_shaft;

{214 Scapula\_articulates\_with\_vertebral\_column: absent present;

{215 Coracoid\_ventral\_margin,\_shape: rounded broad\_tubercle deep\_flange;

{216 Coracoid,\_shape:\_ordered semicircular broad\_shaft narrow\_shaft;

{217 Sternocoracoid\_articulations,\_position\_with\_respect\_to\_one\_another: lateral anterior\_and\_posterior;

{218 Sternum,\_constriction\_posterior\_to\_sternocoracoid\_articulations: present absent;

{219 Cristopine,\_shape: shallow deep;

{220 Cristospine,\_length: stout elongate;

{221 Sternocoracoid\_articulations,\_shape: flattened oval;

{222 Sternocoracoid\_articulations,\_posterior\_expansion: absent present;

{223 Sternum\_plate,\_shape: narrow quadrangular semicircular triangular laterally\_expanded;

{224 Humerus\_proximal\_end\_ventral\_surface,\_pneumatic\_foramen: absent present;

{225 Humerus\_proximal\_end,\_cross\_section: crescent horseshoe;

{226 Humerus\_proximal\_end\_dorsal\_surface,\_pneumatic\_foramen: absent present;

{227 Humerus\_shaft,\_shape: straight bowed;

{228 Humerus,\_mid-shaft,\_shape: tapered subcylindrical;

{229 Humerus\_entepicondyle,\_anteroposterior\_width\_relative\_to\_ectepicondyle\_anteroposterior\_width: entepicondyle\_wider\_than\_ectepicondyle entepicondyle\_at\_most\_ectepicondyle\_width;

{230 Humerus,\_between\_distal\_condyles,\_pneumatic\_foramen: absent present;

{231 Humerus\_distal\_aspect,\_pneumatic\_foramen: absent present;

{232 Humerus\_distal\_aspect,\_shape: hourglass crescentic\_or\_D-shape triangular trapezoidal;

{233 Deltopectoral\_crest,\_position\_on\_humerus: proximal more\_distally\_on\_shaft;

{234 Humerus\_deltopectoral\_crest,\_shape: subtriangular\_with\_proximal\_apex proximally\_leaning\_trapezoid proximally\_curving\_hook oblong\_process\_with\_constricted\_neck low\_and\_rectangular elongate\_and\_proximally\_expanded hatchet-shape distally\_leaning\_trapezoid tall\_rectangular\_process;

{235 Humerus\_deltopectoral\_crest,\_curvature: parallel\_to\_shaft warped\_distally;

{236 Ulnar\_crest\_of\_humerus,\_size: reduced developed;

{237 Humerus\_ulnar\_crest,\_orientation: posterior ventral;

{238 Ulna\_shaft\_proximal\_anterior\_surface,\_shape: flat longitudinal\_ridge;

{239 Ulna\_distal\_tubercle,\_position: middle\_of\_the\_distal\_end ventral\_part\_of\_the\_distal\_end;

{240 Radius\_distal\_end\_cross-section,\_shape: suboval subtriangular\_with\_large\_anterior\_process;

{241 Distal\_syncarpal\_ventral\_articular\_facet\_for\_Metacarpal\_IV,\_size\_relative\_to\_dorsal\_facet: ventral\_facet\_larger subequal\_in\_size;

{242 Distal\_syncarpal,\_cross-section\_shape: rectangular triangular;

{243 Pteroid,\_shape: angled\_at\_midsection stout\_hook straight\_and\_tapered\_with\_expanded\_proximal\_end straight\_with\_expanded\_ends curved\_slender\_rod curved\_and\_subparallel-sided;

{244 Preaxial\_carpal,\_shape: longer\_than\_wide at\_most\_long\_as\_wide;

{245 Metacarpals,\_number\_articulating\_with\_carpus:\_ordered four\_or\_more two one;

{246 Metacarpals\_I\_to\_III\_distal\_ends,\_positions: disparate approximate;

{247 Metacarpal\_IV\_proximal\_cross-section,\_shape: anteroposteriorly\_compressed subrectangular;

{248 Metacarpal\_IV\_shaft\_cross-section,\_shape: rounded\_rectangle anteroposteriorly\_compressed\_oval;

{249 Metacarpal\_distal\_end\_between\_condyles,\_shape: flat median\_ridge;

{250 Manual\_unguals,\_size\_relative\_to\_pedal\_unguals: less\_than\_twice\_the\_size\_of\_pedal\_unguals at\_least\_twice\_the\_size\_of\_pedal\_unguals;

{251 Manual\_digit\_IV\_first\_phalanx\_proximal\_end\_ventral\_surface,\_pneumatic\_foramen: absent present;

{252 Manual\_digit\_IV\_second\_or\_third\_phalanges\_shaft\_cross-sections,\_shape: round\_to\_subtriangular concave\_posteriorly oval ventral\_ridge;

{253 Pubis\_anterior\_margin,\_shape\_in\_lateral\_view:\_ordered convex straight slightly\_concave deeply\_concave;

{254 Pubis\_and\_ischium\_contact,\_shape: confluent\_along\_length partially\_separated\_by\_oval\_opening;

{255 Ischium\_ventral\_margin,\_shape: straight convex;

{256 Prepubis\_shaft,\_constriction: absent present;

{257 Prepubis,\_shape: elongate\_paddle medially\_curved\_with\_short\_lateral\_process triradiate expanded\_fan;

{258 Ilium\_preactetabular\_anterior\_margin,\_shape: rounded pointed;

{259 Ilium\_preacetabular\_process,\_orientation: straight dorsiflected;

{260 Ilium\_postacetabular\_process,\_orientation: subhorizontal posterodorsal;

{261 Ilium\_postacetabular\_process\_shaft,\_constriction: absent present;

{262 Ilium\_postacetabular\_process,\_terminal\_expansion: absent present;

{263 Acetabulum,\_shape: anteroposteriorly\_ovate subcircular;

{264 Ilium\_postacetabular\_process\_apex,\_shape: flat torus;

{265 Femur,\_shape: strongly\_bowed slight\_curvature;

{266 Femur\_proximal\_end,\_pneumatic\_foramen: absent present;

{267 Femoral\_neck,\_shape: indistinct constricted;

{268 Greater\_trochanter,\_shape:\_ordered reduced distinct\_process anteriorly-curved\_hook;

{269 Femur\_distal\_end,\_epicondyles\_size: reduced\_and\_confluent\_with\_distal\_condyles expanded\_into\_distinct\_distal\_flanges;

{270 Femoral\_head,\_angle\_relative\_to\_shaft: at\_most\_145° greater\_than\_145°;

{271 Metatarsal\_IV,\_length\_relative\_to\_metatarsals\_I\_to\_III: subequal significantly\_shorter;

{272 Pedal\_digit\_V,\_number\_of\_phalanges:\_ordered four three two one zero;

{273 Pedal\_digit\_V\_ultimate\_phalanx,\_shape:\_ordered straight curved bent\_at\_midsection nubbin;

{274 (NEW to Longrich et al., 2018; from Lü et al., 2018) Posterior\_region\_of\_skull\_rounded: absent present;

{275 (NEW to Longrich et al., 2018; from Lü et al., 2018) The\_first\_digit\_of\_the\_pedes\_reversed: absent present;

{276 (NEW to Longrich et al., 2018; from Hone, 2020) Metacarpal\_IV\_shape: straight curves\_posteriorly\_at\_the\_distal\_end;

{277 (NEW to Longrich et al., 2018; from Hone, 2020) Manual\_unguals\_on\_each\_respective\_digit\_measured\_along\_the\_dorsal\_edge\_of\_the\_ungula: approximately\_as\_long\_as\_the\_penultimate\_phalanx\_or\_shorter distinctly\_longer;

{278 (NEW to Longrich et al., 2018; from Hone, 2020) Metatarsal\_V\_more\_robust\_than\_metatarsal\_I-IV: absent present;

{279 (NEW to Longrich et al., 2018; from Hone, 2020) Dorsoventral\_height\_of\_pedal\_ungual: more\_than\_twice\_that\_of\_the\_preceding\_phalanx less\_than\_twice\_that\_of\_the\_preceding\_phalanx;

{280 (NEW to Longrich et al., 2018; from Hone, 2020) Dorsal\_ribs\_in\_the\_anterior\_portion\_of\_the\_body: straight\_or\_gently\_curved distinctly\_curved;

{281 (NEW to Longrich et al., 2018; from Hone, 2020) Robust\_first\_phalanx\_of\_pedal\_digit\_V: absent present;

{282 (NEW to Longrich et al., 2018; from Wei et al., 2021) Deltopectoral\_crest,\_projection: scarcely\_developed\_(less\_wide\_than\_humeral\_shaft) well-developed\_and\_projecting;

{283 (NEW to Longrich et al., 2018; from Wei et al., 2021) Humerus\_ulnar\_crest,\_shape: triangular trapezoidal rounded;

{284 (NEW to Longrich et al., 2018; from Wei et al., 2021) Broadness\_of\_the\_jaws\_in\_occlusal\_view: narrowing\_to\_a\_point describing\_a\_semi-ellipse describing\_a\_semi-circle;

{285 (NEW to Longrich et al., 2018; from Wei et al., 2021) Deltopectoral\_crest,\_size\_relative\_to\_humeral\_head:\_ordered longer\_than\_the\_width\_of\_humeral\_head subequal\_to\_the\_width\_of\_humeral\_head shorter\_than\_the\_width\_of\_humeral\_head extremely\_reduced

# SUPPLEMENTAL RESULTS

## Supplemental Figures



FIGURE S1. The counter-slab of NJU-57003.

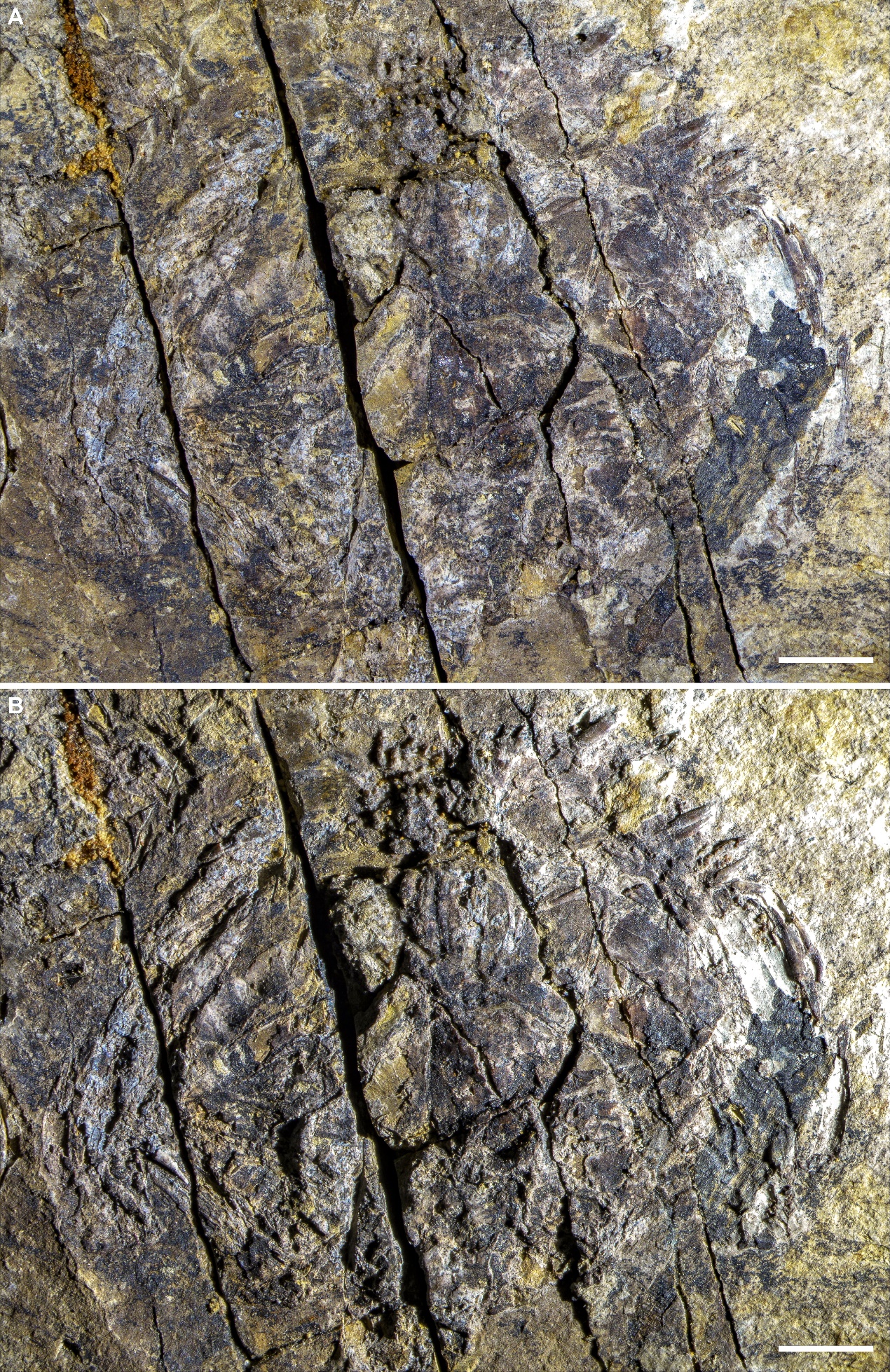


FIGURE S2 (previous page). Close-ups of the skull of NJU-57003 (main slab) under front lighting (**A**) and side lighting (**B**). Scale bars equal 5 mm.

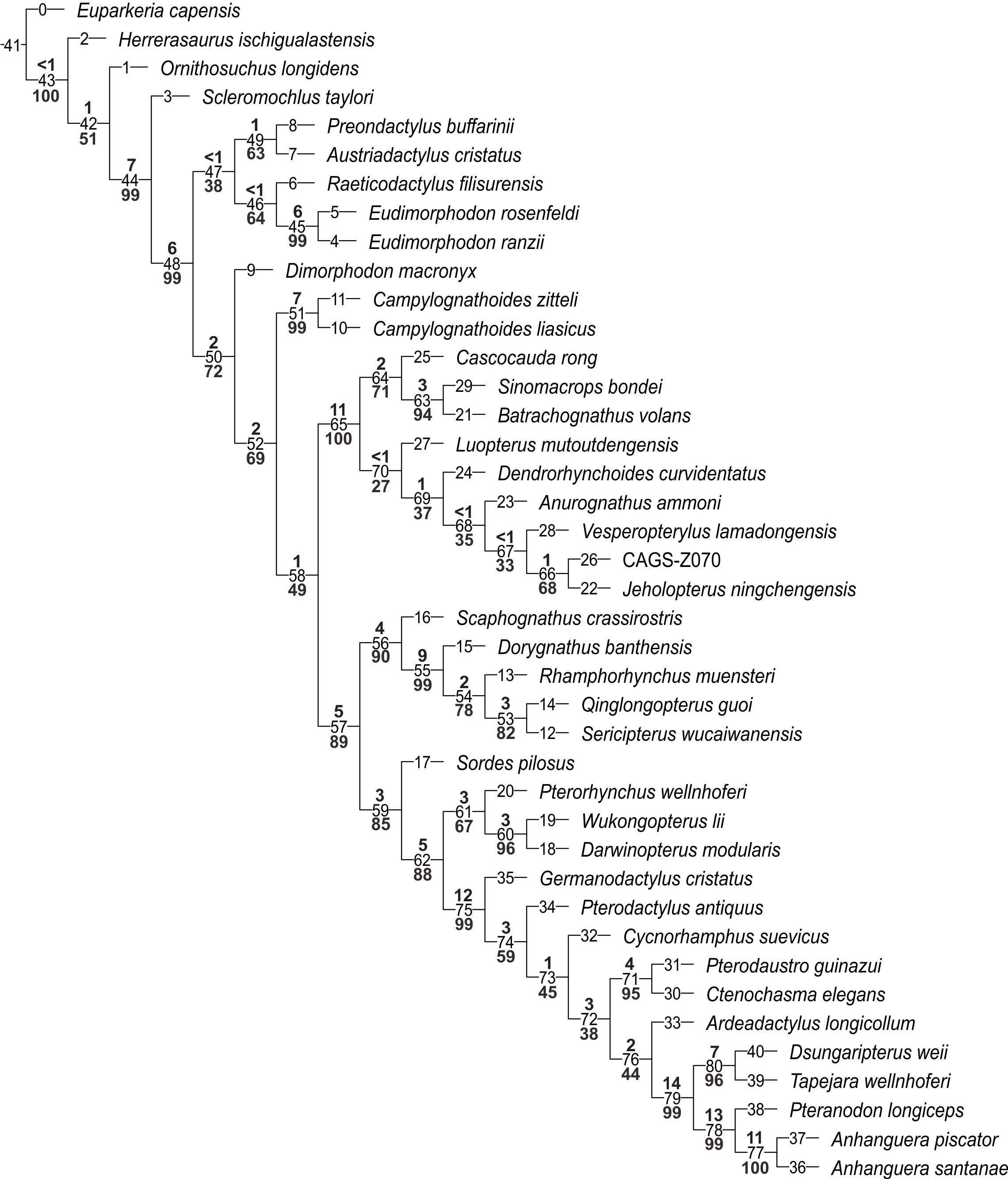


FIGURE S3. Single most parsimonious tree based on Supplemental Data 3 with a length of 850.283 steps (CI=0.442; RI=0.707). Bremer support and bootstrap values for the ingroup nodes are shown above and below branches, respectively.

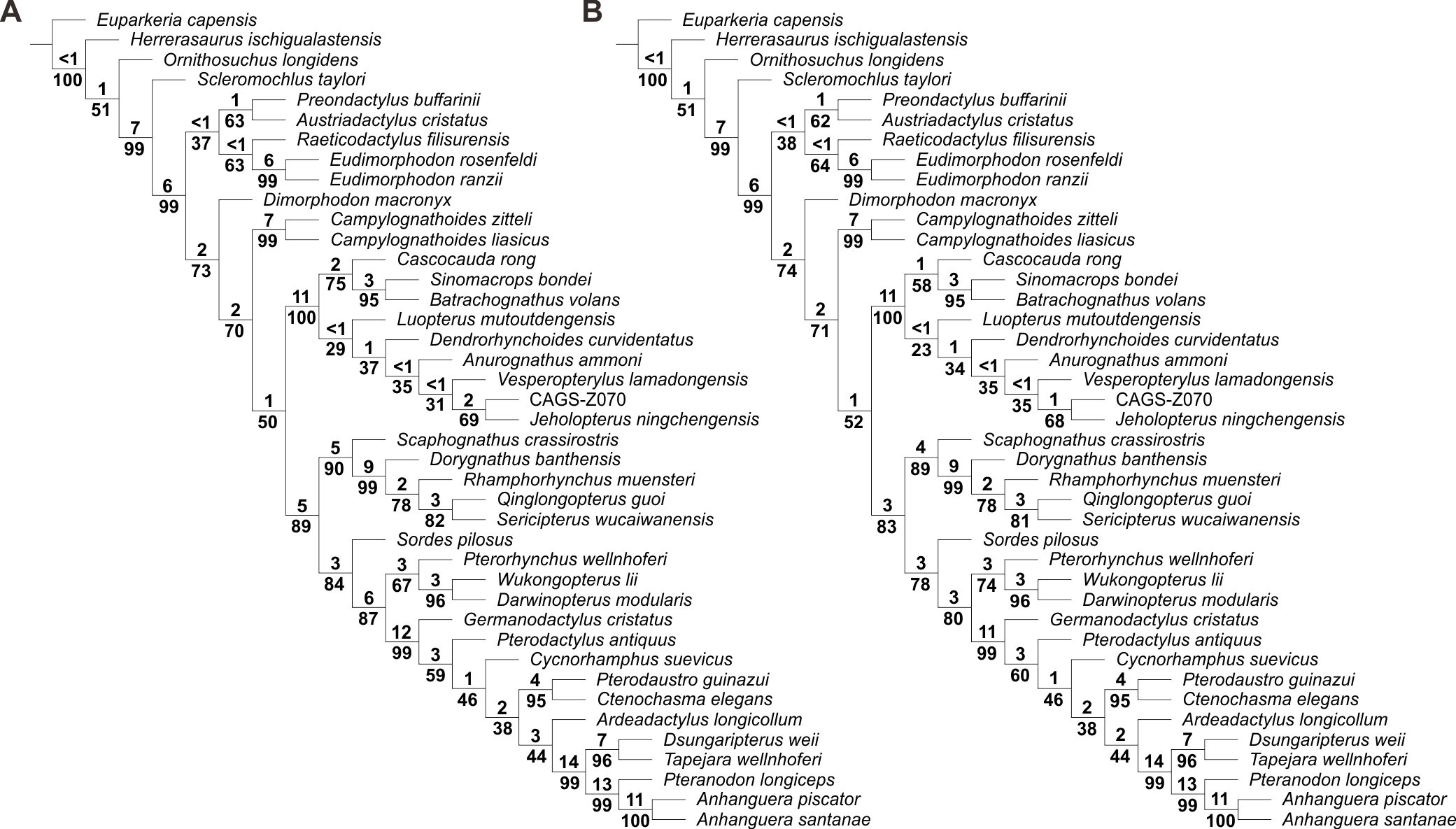


FIGURE S4. Single most parsimonious trees based on Supplemental Data 4 (A) (tree length=852.302 steps; CI=0.441; RI=0.707) and Supplemental Data 5 (B) (tree length=853.227 steps; CI=0.441; RI=0.707). Bremer support and bootstrap values for the ingroup nodes are shown above and below branches, respectively.

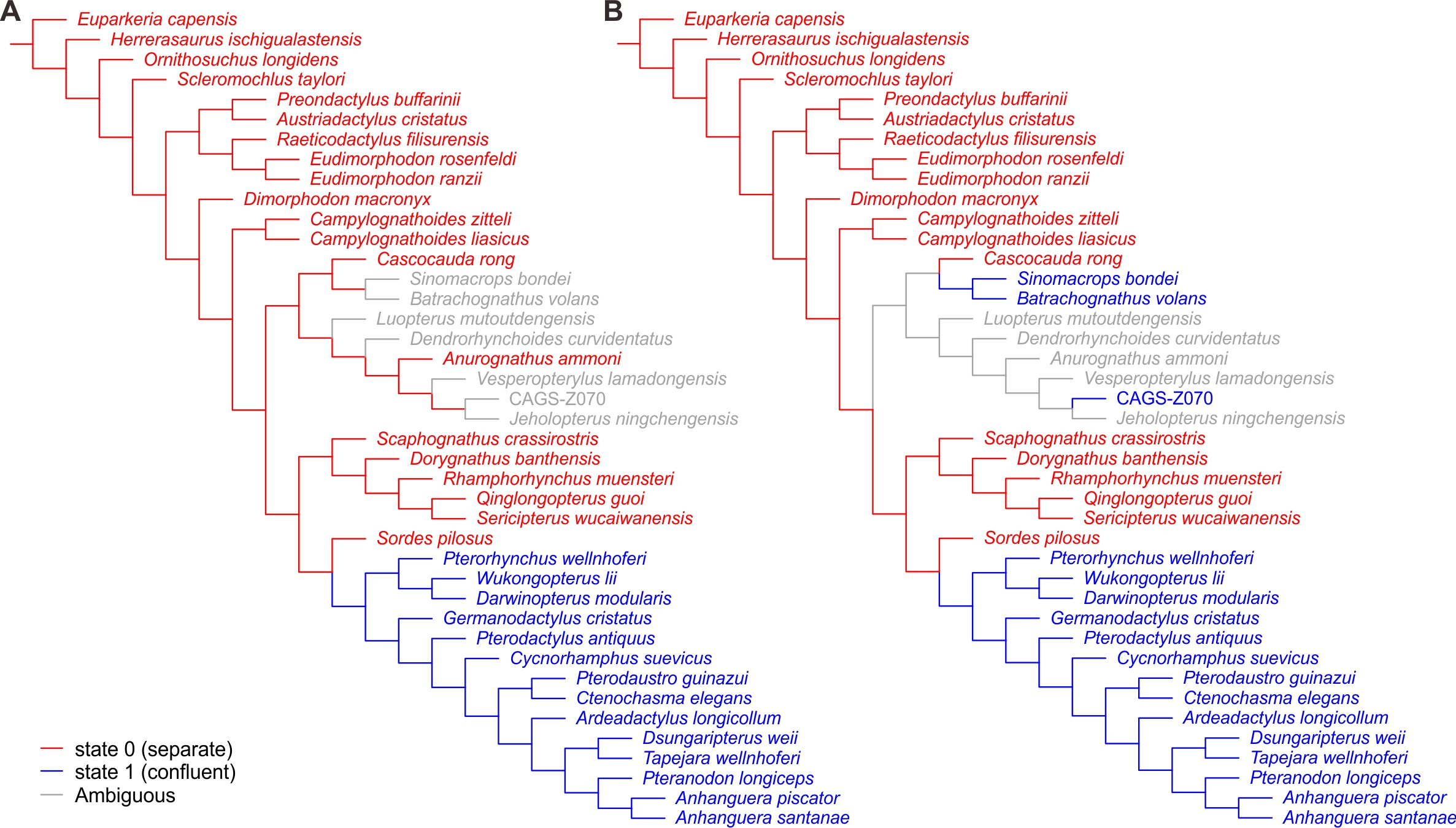


FIGURE S5 (previous page). Character mapping of Char. 74, configuration of external naris and antorbital fenestra, based on Supplemental Data 3 (A) and Supplemental Data 5 (B).

## Supplemental Phylogenetic Results

Four synapomorphies support Batrachognathinae in our analysis (with character state given after each character): Char. 53 (0.017), ratio of length to mid-width of the first phalanx of pedal digit IV (1.7); Char. 282 (0), deltopectoral crest projection (less wide than humerus shaft); Char. 283 (2), humerus ulnar crest shape (rounded); and Char. 285 (2), deltopectoral crest size (shorter than the width of humeral head). The clade (*Batrachognathus volans* + *Sinomacrops bondei*) is supported by following six synapomorphies: Char. 3 (0.090), length ratio of rostrum to skull (0.09); Char. 14 (0.057), length ratio of rostral tooth row to skull (0.09); Char. 16 (0.053), length ratio of mandibular symphysis to mandible (0.09); Char. 234 (4), humerus deltopectoral crest shape (low and rectangular); Char. 279 (1), dorsoventral height of pedal ungual (less than twice that of the preceding phalanx); Char. 284 (1), broadness of the jaws in occlusal view (describing a semi-ellipse).

Anurognathinae is supported by three synapomorphies: Char. 25 (0.125), ratio of length to diameter of single caudal vertebra (2.0); Char. 49 (0.031), length ratio of tail to humerus (0.66); and Char. 50 (0.138–0.146), length ratio of tibia to humerus (about 1.0).

Within Anurognathinae, the clade separated from *Luopterus mutoudengensis* is supported by six synapomorphies: Char. 25 (0.005–0.015), ratio of length to diameter of single caudal vertebra (0.90–1.0); Char. 26 (0.206), length ratio of scapula to coracoid (1.2); Char. 30 (0.568–0.656), length ratio of ulna/radius to humerus (ca. 1.4); Char. 51 (0.141–0.144), length ratio of tibia to ulna (ca. 0.75); Char. 208 (1), number of caudal vertebrae (at most 15); and Char. 209 (0), length of caudal vertebra zygapophyses (short).

The clade composed of *Anurognathus ammoni*, *Vesperopterylus lamadongensis*, *Jeholopterus ningchengensis* and CAGS-Z070 is supported by the following synapomorphies: Char. 22 (0.241), ratio of length to diameter of single dorsal vertebra (1.3); Char. 24 (0.006), length ratio of single caudal vertebra to dorsal vertebra (0.47); Char. 34 (0.330), ratio of metacarpal IV mid-width to ulna and radius combined mid-width (0.42); Char. 35 (0.425), ratio of dorsoventral width to mid-width at the proximal end of metacarpal IV (2.0); Char. 234 (1), humerus deltopectoral crest shape (proximally leaning trapezoid); and Char. 278 (1), metatarsal V more robust than metatarsal I-IV (present).

Further, the monophyly of *Vesperopterylus lamadongensis*, *Jeholopterus ningchengensis* and specimen CAGS-Z070 is supported by four synapomorphies: Char. 15 (0.012–0.016), number of teeth (24–28); Char. 55 (0.129–0.137), ratio of length to mid-width of the third phalanx of pedal digit IV (about 0.90); Char. 280 (1), shape of dorsal ribs from the anterior portion of the body (distinctly curved); and Char. 281 (1), robust first phalanx of pedal digit V (present). The sister-group relationship between *Jeholopterus ningchengensis* and CAGS-Z070 is supported by 13 synapomorphies (see below for details).

Synapomorphies are listed below for the internal nodes of Fig. S3:

Node 42:

Char. 2: 0.611 --> 0.487-0.592

Char. 3: 0.034 --> 0.043

Char. 4: 0.093 --> 0.102-0.411

Char. 10: 0.270 --> 0.349-0.422

Char. 23: 0.000 --> 0.125

Char. 28: 0.068 --> 0.152

Char. 47: 0.075 --> 0.264

Char. 48: 0.150 --> 0.308

Char. 52: 0.334 --> 0.434

Char. 53: 0.081 --> 0.302

Char. 54: 0.139 --> 0.247-0.373

Char. 83: 0 --> 1

Char. 285: 2 --> 1

Node 43:

No synapomorphies

Node 44:

Char. 1: 0.491 --> 0.359-0.376

Char. 3: 0.043 --> 0.197

Char. 6: 0.642-0.725 --> 0.567

Char. 17: 0.132-0.210 --> 0.358-0.364

Char. 22: 0.051-0.379 --> 0.683-0.701

Char. 23: 0.125 --> 0.250

Char. 24: 0.084-0.103 --> 0.117

Char. 28: 0.152 --> 0.394

Char. 30: 0.055-0.060 --> 0.089

Char. 31: 0.575-0.758 --> 0.458

Char. 42: 0.024-0.083 --> 0.208-0.237

Char. 44: 0.016-0.067 --> 0.218

Char. 52: 0.434 --> 0.529

Char. 56: 0 --> 1

Char. 65: 0 --> 1

Char. 72: 0 --> 1

Char. 94: 0 --> 1

Char. 114: 0 --> 12

Char. 119: 0 --> 1

Char. 164: 0 --> 2

Char. 265: 0 --> 1

Char. 279: 1 --> 0

Node 45:

Char. 2: 0.382-0.407 --> 0.349

Char. 5: 0.521 --> 0.744

Char. 6: 0.525 --> 0.321

Char. 10: 0.349-0.422 --> 0.694

Char. 19: 0.601-0.662 --> 0.754

Char. 20: 0.064-0.084 --> 0.042

Char. 32: 0.128-0.177 --> 0.262

Char. 80: 0 --> 1

Char. 115: 0 --> 1

Char. 155: 0 --> 1

Char. 164: 2 --> 1

Char. 180: 0 --> 1

Char. 186: 3 --> 4

Node 46:

Char. 3: 0.204-0.251 --> 0.352

Char. 21: 0.169-0.248 --> 0.255-0.261

Char. 22: 0.683-0.701 --> 0.731-0.777

Char. 36: 0.375-0.402 --> 0.460

Char. 37: 0.529-0.618 --> 0.404

Char. 44: 0.474 --> 0.537

Char. 50: 0.329-0.389 --> 0.222

Char. 51: 0.341 --> 0.204

Char. 81: 0 --> 1

Char. 146: 0 --> 1

Char. 183: 0 --> 1

Char. 186: 1 --> 3

Char. 187: 1 --> 2

Char. 191: 0 --> 1

Node 47:

Char. 2: 0.438 --> 0.382-0.407

Char. 5: 0.375-0.455 --> 0.509-0.521

Char. 24: 0.222-0.236 --> 0.454-0.834

Char. 28: 0.426 --> 0.433-0.435

Char. 30: 0.494 --> 0.496-0.547

Char. 52: 0.529-0.712 --> 0.944

Char. 173: 0 --> 1

Node 48:

Char. 2: 0.487-0.592 --> 0.438

Char. 3: 0.197 --> 0.204-0.251

Char. 4: 0.102-0.411 --> 0.413-0.478

Char. 7: 0.604-0.626 --> 0.539-0.573

Char. 13: 0.697 --> 0.576-0.602

Char. 19: 0.398-0.417 --> 0.601-0.662

Char. 20: 0.158 --> 0.064-0.084

Char. 21: 0.065-0.088 --> 0.169-0.248

Char. 24: 0.117 --> 0.222-0.236

Char. 25: 0.209 --> 0.507-0.539

Char. 26: 0.530-0.795 --> 0.321-0.335

Char. 28: 0.394 --> 0.426

Char. 30: 0.089 --> 0.494

Char. 31: 0.458 --> 0.427

Char. 33: 0.001-0.030 --> 0.153

Char. 34: 0.085-0.109 --> 0.448

Char. 36: 0.001 --> 0.375-0.402

Char. 43: 0.681 --> 0.264-0.332

Char. 44: 0.218 --> 0.474

Char. 45: 0.994 --> 0.575

Char. 46: 0.873 --> 0.620-0.708

Char. 51: 0.669 --> 0.341-0.355

Char. 97: 0 --> 12

Char. 129: 0 --> 1

Char. 137: 0 --> 1

Char. 170: 1 --> 0

Char. 177: 0 --> 2

Char. 216: 0 --> 1

Char. 227: 0 --> 1

Node 49:

Char. 0: 0.157-0.180 --> 0.192

Char. 10: 0.349-0.422 --> 0.348

Char. 16: 0.115 --> 0.112

Char. 17: 0.358-0.364 --> 0.421

Char. 30: 0.496-0.547 --> 0.568

Char. 100: 0 --> 1

Node 50:

Char. 45: 0.575 --> 0.521-0.565

Char. 48: 0.561 --> 0.848-0.865

Char. 71: 0 --> 1

Char. 84: 0 --> 1

Char. 95: 0 --> 1

Char. 161: 0 --> 1

Char. 164: 2 --> 3

Char. 168: 0 --> 1

Char. 178: 0 --> 1

Char. 185: 0 --> 1

Char. 209: 0 --> 2

Char. 216: 1 --> 2

Char. 229: 0 --> 1

Char. 253: 0 --> 1

Char. 255: 0 --> 1

Char. 260: 0 --> 1

Char. 263: 0 --> 1

Node 51:

Char. 5: 0.375-0.455 --> 0.476

Char. 7: 0.514-0.573 --> 0.627

Char. 10: 0.411-0.431 --> 0.561

Char. 20: 0.064-0.084 --> 0.113

Char. 28: 0.426 --> 0.299

Char. 30: 0.494 --> 0.439

Char. 32: 0.100-0.177 --> 0.203

Char. 36: 0.398-0.564 --> 0.621

Char. 44: 0.474 --> 0.433

Char. 119: 1 --> 0

Char. 142: 1 --> 2

Char. 191: 0 --> 1

Char. 219: 0 --> 1

Char. 220: 1 --> 0

Char. 226: 0 --> 1

Char. 240: 0 --> 1

Char. 252: 0 --> 1

Char. 258: 0 --> 1

Node 52:

Char. 6: 0.525-0.567 --> 0.328-0.485

Char. 39: 0.737 --> 0.617-0.630

Char. 40: 0.173 --> 0.080-0.098

Char. 42: 0.237 --> 0.647-0.662

Char. 43: 0.264 --> 0.135-0.188

Char. 50: 0.329-0.389 --> 0.211-0.217

Char. 51: 0.341-0.355 --> 0.152

Char. 52: 0.529-0.712 --> 0.451-0.453

Char. 53: 0.302-0.328 --> 0.148-0.244

Char. 54: 0.247-0.459 --> 0.188-0.210

Char. 141: 0 --> 1

Char. 154: 0 --> 1

Char. 180: 0 --> 1

Char. 189: 1 --> 0

Char. 268: 0 --> 1

Char. 273: 0 --> 1

Node 53:

Char. 15: 0.020-0.024 --> 0.016

Char. 26: 0.198 --> 0.135

Char. 28: 0.273 --> 0.259

Char. 31: 0.536-0.582 --> 0.673

Char. 56: 2 --> 3

Char. 176: 0 --> 1

Char. 182: 0 --> 1

Char. 239: 1 --> 0

Node 54:

Char. 0: 0.211 --> 0.217

Char. 16: 0.441 --> 0.460

Char. 17: 0.364 --> 0.450

Char. 19: 0.649 --> 0.690

Char. 21: 0.287-0.333 --> 0.227-0.284

Char. 26: 0.266 --> 0.198

Char. 28: 0.361 --> 0.273

Char. 33: 0.186 --> 0.189

Char. 36: 0.409 --> 0.423-0.601

Char. 37: 0.645-0.661 --> 0.356-0.493

Char. 38: 0.696-0.711 --> 0.573

Char. 46: 0.598 --> 0.637

Char. 47: 0.630-0.729 --> 0.450

Char. 48: 0.746 --> 0.659

Char. 56: 1 --> 2

Char. 184: 1 --> 2

Char. 188: 1 --> 0

Node 55:

Char. 0: 0.157-0.202 --> 0.211

Char. 3: 0.353 --> 0.456-0.475

Char. 5: 0.375-0.455 --> 0.736

Char. 14: 0.736 --> 0.784-0.866

Char. 16: 0.249-0.406 --> 0.441

Char. 19: 0.570 --> 0.649

Char. 20: 0.064-0.084 --> 0.112

Char. 24: 0.222 --> 0.253-0.256

Char. 28: 0.394 --> 0.361

Char. 33: 0.183 --> 0.186

Char. 41: 0.524 --> 0.702

Char. 42: 0.647 --> 0.623

Char. 48: 0.848-0.865 --> 0.746

Char. 52: 0.258 --> 0.347-0.377

Char. 53: 0.148-0.244 --> 0.534-0.538

Char. 54: 0.051-0.109 --> 0.236-0.239

Char. 69: 0 --> 1

Char. 75: 0 --> 1

Char. 94: 1 --> 0

Char. 140: 0 --> 1

Char. 181: 0 --> 1

Char. 183: 0 --> 1

Char. 191: 0 --> 1

Char. 285: 1 --> 0

Node 56:

Char. 28: 0.426-0.471 --> 0.394

Char. 39: 0.630 --> 0.741-0.853

Char. 73: 0 --> 1

Char. 161: 1 --> 0

Char. 165: 0 --> 1

Char. 173: 3 --> 2

Char. 175: 0 --> 1

Char. 234: 0 --> 3

Char. 239: 0 --> 1

Node 57:

Char. 16: 0.115 --> 0.249-0.406

Char. 21: 0.173-0.248 --> 0.287-0.333

Char. 30: 0.719-0.786 --> 0.837-0.856

Char. 34: 0.448-0.563 --> 0.573-0.589

Char. 37: 0.572-0.618 --> 0.645

Char. 45: 0.521-0.565 --> 0.210-0.456

Char. 46: 0.620-0.708 --> 0.475-0.598

Char. 117: 0 --> 1

Char. 148: 0 --> 1

Char. 170: 1 --> 2

Char. 223: 1 --> 2

Char. 250: 0 --> 1

Char. 259: 0 --> 1

Char. 271: 0 --> 1

Char. 273: 1 --> 2

Char. 279: 0 --> 1

Node 58:

Char. 14: 0.760-0.814 --> 0.671-0.736

Char. 15: 0.044-0.054 --> 0.020-0.024

Char. 19: 0.601-0.694 --> 0.527-0.570

Char. 25: 0.507-0.539 --> 0.389-0.456

Char. 30: 0.494 --> 0.719-0.786

Char. 31: 0.427 --> 0.536-0.551

Char. 49: 0.641 --> 0.440-0.496

Char. 51: 0.152 --> 0.112-0.137

Char. 52: 0.451-0.453 --> 0.220-0.258

Char. 54: 0.188-0.210 --> 0.096-0.109

Char. 67: 0 --> 1

Char. 170: 0 --> 1

Char. 173: 0 --> 3

Char. 178: 1 --> 2

Char. 179: 1 --> 0

Char. 246: 0 --> 1

Node 59:

Char. 17: 0.358-0.364 --> 0.463-0.527

Char. 26: 0.266 --> 0.261

Char. 28: 0.426-0.471 --> 0.522-0.608

Char. 34: 0.573-0.589 --> 0.609

Char. 42: 0.647-0.662 --> 0.706-0.746

Char. 52: 0.220-0.258 --> 0.139-0.194

Char. 55: 0.357-0.591 --> 0.116-0.287

Char. 100: 0 --> 1

Char. 113: 0 --> 1

Char. 115: 0 --> 1

Char. 243: 2 --> 4

Node 60:

Char. 14: 0.671-0.686 --> 0.659

Char. 15: 0.026-0.040 --> 0.042

Char. 38: 0.830 --> 0.929

Char. 39: 0.674 --> 0.977

Char. 184: 1 --> 3

Char. 188: 1 --> 2

Char. 263: 1 --> 0

Node 61:

Char. 24: 0.222 --> 0.364

Char. 25: 0.389-0.456 --> 0.563-0.734

Char. 37: 0.645 --> 0.780-0.981

Char. 38: 0.696 --> 0.830

Char. 39: 0.630 --> 0.674

Char. 41: 0.627-0.689 --> 0.719

Char. 45: 0.188-0.201 --> 0.167

Char. 164: 3 --> 0

Char. 182: 0 --> 1

Char. 193: 0 --> 1

Char. 229: 1 --> 0

Node 62:

Char. 3: 0.256-0.353 --> 0.439

Char. 11: 0.384-0.492 --> 0.231

Char. 13: 0.508-0.602 --> 0.321

Char. 15: 0.020-0.024 --> 0.026-0.040

Char. 20: 0.064-0.084 --> 0.123-0.233

Char. 22: 0.683-0.841 --> 0.410-0.506

Char. 32: 0.109 --> 0.206

Char. 33: 0.153-0.183 --> 0.207-0.228

Char. 41: 0.484-0.524 --> 0.627-0.689

Char. 45: 0.210 --> 0.188-0.201

Char. 48: 0.848-0.865 --> 0.569-0.804

Char. 74: 0 --> 1

Char. 79: 2 --> 4

Char. 197: 0 --> 1

Char. 201: 0 --> 1

Char. 202: 0 --> 1

Char. 260: 1 --> 0

Node 63:

Char. 3: 0.093-0.124 --> 0.090

Char. 14: 0.060-0.092 --> 0.057

Char. 16: 0.057-0.093 --> 0.053

Char. 234: 0 --> 4

Char. 279: 0 --> 1

Char. 284: 2 --> 1

Node 64:

Char. 53: 0.021-0.193 --> 0.017

Char. 282: 1 --> 0

Char. 283: 0 --> 2

Char. 285: 1 --> 2

Node 65:

Char. 1: 0.359-0.376 --> 0.000

Char. 2: 0.438 --> 0.776-0.782

Char. 3: 0.251-0.307 --> 0.093-0.124

Char. 4: 0.422 --> 0.026

Char. 5: 0.375-0.455 --> 0.004

Char. 6: 0.328-0.485 --> 0.239

Char. 7: 0.514-0.573 --> 0.162

Char. 14: 0.671-0.736 --> 0.060-0.092

Char. 16: 0.115 --> 0.057-0.093

Char. 19: 0.527-0.570 --> 0.460-0.514

Char. 22: 0.683-0.708 --> 0.260-0.275

Char. 24: 0.222 --> 0.105

Char. 25: 0.389-0.456 --> 0.147-0.163

Char. 32: 0.087-0.109 --> 0.039

Char. 33: 0.153 --> 0.115

Char. 34: 0.448-0.563 --> 0.432

Char. 35: 0.527-0.604 --> 0.450

Char. 37: 0.572-0.618 --> 0.082

Char. 38: 0.577-0.696 --> 0.166

Char. 39: 0.617-0.630 --> 0.000

Char. 43: 0.135-0.188 --> 0.120

Char. 46: 0.620-0.708 --> 0.780

Char. 49: 0.440-0.496 --> 0.120-0.124

Char. 64: 0 --> 1

Char. 67: 1 --> 3

Char. 68: 1 --> 0

Char. 70: 1 --> 0

Char. 75: 0 --> 1

Char. 82: 0 --> 1

Char. 98: 0 --> 1

Char. 116: 0 --> 1

Char. 136: 0 --> 1

Char. 137: 1 --> 0

Char. 144: 0 --> 1

Char. 150: 0 --> 2

Char. 162: 0 --> 1

Char. 164: 3 --> 2

Char. 201: 0 --> 1

Char. 209: 2 --> 1

Char. 243: 2 --> 5

Char. 280: 1 --> 0

Char. 284: 0 --> 2

Node 66:

Char. 3: 0.094 --> 0.103

Char. 14: 0.062 --> 0.071

Char. 16: 0.058 --> 0.069

Char. 20: 0.064 --> 0.049

Char. 21: 0.173 --> 0.164

Char. 31: 0.530-0.555 --> 0.503

Char. 36: 0.558 --> 0.503

Char. 44: 0.454-0.474 --> 0.375

Char. 50: 0.138-0.146 --> 0.006

Char. 51: 0.141 --> 0.036

Char. 52: 0.220-0.224 --> 0.151

Char. 54: 0.096 --> 0.089

Char. 277: 0 --> 1

Node 67:

Char. 15: 0.018 --> 0.012-0.016

Char. 55: 0.357-0.501 --> 0.129-0.137

Char. 280: 0 --> 1

Char. 281: 0 --> 1

Node 68:

Char. 22: 0.260 --> 0.241

Char. 24: 0.016 --> 0.006

Char. 34: 0.432 --> 0.330

Char. 35: 0.450 --> 0.425

Char. 234: 0 --> 1

Char. 278: 0 --> 1

Node 69:

Char. 25: 0.125 --> 0.005-0.015

Char. 26: 0.266-0.321 --> 0.206

Char. 30: 0.719-0.786 --> 0.568-0.656

Char. 51: 0.112-0.137 --> 0.141-0.144

Char. 208: 0 --> 1

Char. 209: 1 --> 0

Node 70:

Char. 25: 0.147-0.163 --> 0.125

Char. 49: 0.120-0.124 --> 0.031

Char. 50: 0.211-0.212 --> 0.138-0.146

Node 71:

Char. 0: 0.342-0.443 --> 0.708

Char. 3: 0.700 --> 0.876

Char. 8: 0.453 --> 0.039

Char. 14: 0.637 --> 0.829

Char. 15: 0.046 --> 0.398

Char. 16: 0.605-0.657 --> 0.913

Char. 19: 0.527-0.672 --> 0.797

Char. 28: 0.564-0.596 --> 0.605

Char. 40: 0.035-0.037 --> 0.054

Char. 41: 0.685-0.690 --> 0.813

Char. 43: 0.301-0.407 --> 0.203

Char. 46: 0.186-0.478 --> 0.585

Char. 47: 0.078 --> 0.017

Char. 48: 0.151 --> 0.004

Char. 50: 0.413-0.433 --> 0.365

Char. 51: 0.325-0.338 --> 0.315

Char. 66: 0 --> 1

Char. 101: 1 --> 2

Char. 170: 2 --> 1

Char. 178: 2 --> 1

Node 72:

Char. 3: 0.561-0.641 --> 0.700

Char. 16: 0.569 --> 0.605-0.657

Char. 31: 0.489 --> 0.414-0.425

Char. 182: 0 --> 1

Char. 195: 0 --> 1

Char. 199: 0 --> 1

Node 73:

Char. 11: 0.192-0.231 --> 0.246-0.251

Char. 26: 0.261 --> 0.207

Char. 31: 0.492-0.551 --> 0.489

Char. 36: 0.435-0.461 --> 0.539-0.696

Char. 37: 0.358-0.363 --> 0.099-0.309

Char. 38: 0.437-0.455 --> 0.157-0.306

Char. 39: 0.516 --> 0.375-0.478

Char. 44: 0.501-0.543 --> 0.550-0.587

Char. 45: 0.188 --> 0.145

Char. 68: 1 --> 2

Char. 173: 3 --> 2

Char. 175: 0 --> 1

Node 74:

Char. 0: 0.292 --> 0.302-0.443

Char. 3: 0.545 --> 0.561-0.641

Char. 8: 0.564 --> 0.453-0.517

Char. 10: 0.411 --> 0.538-0.636

Char. 14: 0.671-0.686 --> 0.610-0.637

Char. 21: 0.448 --> 0.510-0.636

Char. 24: 0.009 --> 0.008

Char. 39: 0.593 --> 0.516

Char. 43: 0.275 --> 0.301

Char. 50: 0.394 --> 0.413

Char. 52: 0.110 --> 0.103-0.107

Char. 53: 0.165-0.377 --> 0.389-0.447

Char. 112: 0 --> 1

Char. 126: 1 --> 2

Char. 161: 1 --> 0

Char. 274: 0 --> 1

Node 75:

Char. 0: 0.202-0.273 --> 0.292

Char. 3: 0.439 --> 0.545

Char. 16: 0.249-0.406 --> 0.569

Char. 17: 0.463-0.527 --> 0.584

Char. 20: 0.123-0.233 --> 0.532

Char. 22: 0.410-0.506 --> 0.254-0.274

Char. 24: 0.222 --> 0.009

Char. 25: 0.389-0.456 --> 0.062-0.074

Char. 30: 0.837-0.856 --> 0.509-0.547

Char. 32: 0.206 --> 0.628-0.644

Char. 33: 0.207-0.228 --> 0.425-0.476

Char. 35: 0.527-0.604 --> 0.259

Char. 36: 0.391-0.409 --> 0.435-0.461

Char. 37: 0.645 --> 0.358-0.363

Char. 38: 0.696 --> 0.437-0.455

Char. 39: 0.630 --> 0.593

Char. 42: 0.706-0.746 --> 0.763-0.921

Char. 43: 0.168-0.226 --> 0.275

Char. 50: 0.217-0.294 --> 0.394

Char. 51: 0.112-0.199 --> 0.325-0.338

Char. 52: 0.139-0.194 --> 0.110

Char. 54: 0.051-0.109 --> 0.021-0.033

Char. 88: 1 --> 3

Char. 101: 0 --> 1

Char. 107: 0 --> 1

Char. 114: 2 --> 3

Char. 132: 0 --> 1

Char. 177: 2 --> 1

Char. 201: 1 --> 2

Char. 247: 0 --> 1

Char. 248: 1 --> 0

Char. 253: 2 --> 3

Char. 272: 2 --> 3

Char. 273: 2 --> 3

Node 76:

Char. 37: 0.099-0.309 --> 0.091

Char. 39: 0.375-0.478 --> 0.270-0.312

Char. 42: 0.763-0.921 --> 0.658-0.716

Char. 159: 0 --> 1

Char. 173: 2 --> 5

Char. 184: 1 --> 3

Char. 223: 2 --> 1

Char. 224: 0 --> 1

Char. 227: 1 --> 0

Node 77:

Char. 13: 0.153-0.321 --> 0.336

Char. 26: 0.081 --> 0.015

Char. 31: 0.302 --> 0.024

Char. 35: 0.210-0.255 --> 0.260

Char. 52: 0.103-0.107 --> 0.005

Char. 59: 0 --> 1

Char. 79: 4 --> 2

Char. 102: 0 --> 1

Char. 108: 0 --> 1

Char. 110: 2 --> 0

Char. 159: 1 --> 0

Char. 192: 0 --> 1

Char. 207: 1 --> 0

Char. 213: 0 --> 1

Char. 222: 0 --> 1

Char. 224: 1 --> 0

Node 78:

Char. 2: 0.250-0.278 --> 0.300-0.369

Char. 11: 0.246-0.251 --> 0.093-0.113

Char. 16: 0.621-0.657 --> 0.733-0.762

Char. 26: 0.207 --> 0.081

Char. 31: 0.410-0.425 --> 0.302

Char. 42: 0.658-0.716 --> 0.575

Char. 43: 0.301-0.407 --> 0.292

Char. 63: 0 --> 1

Char. 71: 1 --> 0

Char. 99: 0 --> 1

Char. 118: 0 --> 1

Char. 121: 0 --> 1

Char. 198: 0 --> 1

Char. 210: 0 --> 1

Char. 212: 0 --> 1

Char. 217: 1 --> 0

Char. 218: 1 --> 0

Char. 221: 0 --> 1

Char. 228: 1 --> 0

Char. 235: 0 --> 1

Char. 241: 0 --> 1

Char. 242: 0 --> 1

Char. 245: 0 --> 1

Char. 253: 3 --> 2

Char. 270: 0 --> 1

Node 79:

Char. 1: 0.625 --> 0.638

Char. 9: 0.365-0.419 --> 0.048-0.241

Char. 10: 0.538 --> 0.159-0.415

Char. 12: 0.430 --> 0.415

Char. 17: 0.584-0.919 --> 0.545

Char. 20: 0.532-0.739 --> 0.245-0.395

Char. 24: 0.006-0.008 --> 0.016-0.020

Char. 30: 0.509-0.547 --> 0.580-0.621

Char. 32: 0.644 --> 0.607

Char. 67: 1 --> 0

Char. 103: 0 --> 1

Char. 109: 0 --> 1

Char. 111: 1 --> 0

Char. 112: 1 --> 0

Char. 114: 3 --> 2

Char. 126: 2 --> 1

Char. 164: 2 --> 0

Char. 165: 0 --> 12

Char. 193: 0 --> 1

Char. 196: 0 --> 1

Char. 197: 1 --> 0

Char. 202: 1 --> 0

Char. 203: 0 --> 1

Char. 211: 0 --> 1

Char. 219: 0 --> 1

Char. 236: 0 --> 1

Char. 251: 0 --> 1

Char. 260: 0 --> 1

Char. 274: 1 --> 0

Node 80:

Char. 0: 0.342 --> 0.282

Char. 1: 0.638 --> 0.651

Char. 2: 0.250-0.278 --> 0.140

Char. 3: 0.700 --> 0.548

Char. 8: 0.453 --> 0.482

Char. 9: 0.048-0.241 --> 0.044

Char. 11: 0.246-0.251 --> 0.295

Char. 12: 0.415 --> 0.033

Char. 17: 0.545 --> 0.393

Char. 26: 0.207 --> 0.241

Char. 28: 0.564 --> 0.402

Char. 31: 0.410-0.425 --> 0.461

Char. 34: 0.673-0.703 --> 0.769

Char. 43: 0.301-0.407 --> 0.415

Char. 61: 0 --> 1

Char. 87: 0 --> 1

Char. 122: 0 --> 1

Char. 130: 0 --> 1

Char. 151: 0 --> 1

Char. 237: 0 --> 1

Char. 238: 0 --> 1

Char. 239: 0 --> 1

Char. 240: 0 --> 1

Char. 244: 0 --> 1

Char. 261: 0 --> 1

Char. 269: 0 --> 1

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