

Additional file 1

Unappreciated diversification of stem archosaurs during the Middle Triassic predated the dominance of dinosaurs

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Species	Clade	Age	Time	Source
<i>Tanystropheus longobardicus</i>	'Protorosauria'	Anisian-Ladinian	242	Nosotti 2007
<i>Langobardisaurus pandolfii</i>	'Protorosauria'	late Norian	213.1	Saller et al. 2013
<i>Protorosaurus speneri</i>	'Protorosauria'	middle Wuchiapingian	257.3	Gottmann-Quesada and Sander 2009
<i>Prolacerta broomi</i>	Prolacertidae	Induan-early Olenekian	250.7	Ezcurra and Butler 2015a
<i>Proterosuchus fergusi</i>	Proterosuchidae	Induan-early Olenekian	250.7	Ezcurra and Butler 2015b
<i>Proterosuchus alexanderi</i>	Proterosuchidae	Induan-early Olenekian	250.7	Ezcurra and Butler 2015b
<i>Proterosuchus goweri</i>	Proterosuchidae	Induan-early Olenekian	250.7	Ezcurra and Butler 2015b
<i>Trilophosaurus buettneri</i>	Allokotosauria	Norian	217	Sues and Fraser 2010
<i>Azendohsaurus madagaskarensis</i>	Allokotosauria	Ladinian-earliest Carnian	237	Flynn et al. 2010
<i>Bentonyx sidensis</i>	Rhynchosauria	late Anisian	243.3	Hone and Benton 2008
<i>Hyperodapedon gordoni</i>	Rhynchosauria	late Carnian-earliest Norian	228.95	Benton 1983
<i>Hyperodapedon huxleyi</i>	Rhynchosauria	late Carnian-earliest Norian	228.95	Chatterjee 1974
<i>Hyperodapedon sanjuanensis</i>	Rhynchosauria	late Carnian-earliest Norian	228.95	Langer and Schultz 2000
<i>Mesosuchus browni</i>	Rhynchosauria	early Anisian	245.9	Dilkes 1998
<i>Rhynchosaurus articeps</i>	Rhynchosauria	Anisian	244.6	Benton 1990
<i>Rhynchosaurus brodiei</i>	Rhynchosauria	Anisian	244.6	Benton 1990

<i>Teyumbaita sulcognathus</i>	Rhynchosauria	early Norian	222.45	Montefeltro et al. 2010
<i>Erythrosuchus africanus</i>	Erythrosuchidae	early Anisian	245.9	Nesbitt 2011
<i>Garjainia prima</i>	Erythrosuchidae	late Olenekian	248.2	Ezcurra and Butler 2015a
<i>Shansisuchus shansisuchus</i>	Erythrosuchidae	late Anisian	243.3	Wang et al. 2013
<i>Chanaresuchus bonapartei</i>	Proterochampsidae	Ladinian-earliest Carnian	237	Nesbitt 2011
<i>Gualosuchus reigi</i>	Proterochampsidae	Ladinian-earliest Carnian	237	Romer 1971
<i>Euparkeria capensis</i>	Euparkeriidae	early Anisian	245.9	Nesbitt 2011
<i>Parasuchus hislopi</i>	Phytosauria	late Carnian-earliest Norian	228.95	Sereno 1991
<i>Smilosuchus gregorii</i>	Phytosauria	early Norian	222.35	Nesbitt 2011
<i>Brachysuchus megalodon</i>	Phytosauria	late Carnian-early Norian	224.85	Case 1929
<i>Mystriosuchus planirostris</i>	Phytosauria	late Norian	213.1	Hungerbuhler 2002
<i>Mystriosuchus westphali</i>	Phytosauria	late Norian	213.1	Hungerbuhler 2002
<i>Leptosuchus adamanensis</i>	Phytosauria	Norian	217.75	Sues and Fraser 2010
<i>Leptosuchus studeri</i>	Phytosauria	early Norian	222.35	Case and White 1934
<i>Nicrosaurus kapffi</i>	Phytosauria	late Norian	213.1	Westphal 1976
<i>Pseudopalatus pristinus</i>	Phytosauria	late Norian-Rhaetian	209.5	Camp 1930
<i>Riojasuchus tenuisiceps</i>	Ornithosuchidae	middle Norian	216	Nesbitt 2011
<i>Ornithosuchus longidens</i>	Ornithosuchidae	late Carnian-earliest Norian	228.95	Sereno 1991
<i>Gracilisuchus stipanicicorum</i>	Suchia	Ladinian-earliest Carnian	237	Nesbitt 2011
<i>Qianosuchus mixtus</i>	Poposauroida	Anisian	244.6	Li et al. 2006
<i>Effigia okeeffeae</i>	Poposauroida	late Norian-Rhaetian	209.5	Nesbitt 2011
<i>Desmatosuchus smalli</i>	Aetosauria	? late Norian	213.1	Small 2002
<i>Stenomyti huangae</i>	Aetosauria	late Norian-Rhaetian	209.5	Small and Martz 2013

<i>Stagonolepis robertsoni</i>	Aetosauria	late Carnian-earliest Norian	228.95	Sulej 2010
<i>Stagonolepis olenkae</i>	Aetosauria	late Carnian	229.5	Sulej 2010
<i>Neoaetosauroides engaeus</i>	Aetosauria	middle Norian	216	Desojo and Baez 2007
<i>Aetosaurus ferratus</i>	Aetosauria	late Norian	213.1	Schoch 2007
<i>Revueltosaurus callenderi</i>	Aetosauria	Norian-Rhaetian	213.65	Nesbitt 2011
<i>Postosuchus kirkpatricki</i>	Rauisuchidae	Norian-Rhaetian	213.65	Weinbaum 2011
<i>Prestosuchus chiniquiensis</i>	Loricata	Ladinian-earliest Carnian	237	Sues and Fraser 2010
<i>Saurosuchus galilei</i>	Loricata	late Carnian-earliest Norian	228.95	Nesbitt 2011
<i>Batrachotomus kuperferzellensis</i>	Loricata	late Ladinian (Longobardian)	238.25	Nesbitt 2011
<i>Dromicosuchus grallator</i>	Crocodylomorpha	early Norian	222.35	Nesbitt 2011
<i>Protosuchus richardsoni</i>	Crocodylomorpha	Hettangian	200.3	Nesbitt 2011
<i>Dibothrosuchus elaphros</i>	Crocodylomorpha	?Hettangian-Sinemurian	196.05	Wu and Chatterjee 1993
<i>Sphenosuchus acutus</i>	Crocodylomorpha	Hettangian-Sinemurian	196.05	Nesbitt 2011
<i>Pelagosaurus typus</i>	Crocodylomorpha	early Toarcian	179.3	Pierce and Benton 2006
<i>Eudimorphodon ranzii</i>	Pterosauria	late Norian	210	Nesbitt 2011
<i>Campylognathoides spp.</i>	Pterosauria	early Toarcian	182.5	Wellnhofer 1978 (modified)
<i>Dorygnathus banthensis</i>	Pterosauria	early Toarcian	182.5	Wellnhofer 1978 (modified)
<i>Tawa hallae</i>	Theropoda	late Norian-Rhaetian	209.5	Nesbitt 2011
<i>Herrerasaurus ischigualastensis</i>	Theropoda	late Carnian-earliest Norian	228.95	Nesbitt 2011
<i>Coelophysis bauri</i>	Theropoda	late Norian-Rhaetian	209.5	Nesbitt 2011
' <i>Syntarsus</i> ' <i>kayentakatae</i>	Theropoda	Sinemurian-Pliensbachian	191	Tykoski 2005
<i>Zupaysaurus rougieri</i>	Theropoda	middle Norian	216	Ezcurra 2007
<i>Dilophosaurus wetherilli</i>	Theropoda	Sinemurian-Pliensbachian	191	Rauhut 2003

<i>Eoraptor lunensis</i>	Sauropodomorpha	late Carnian-earliest Norian	228.95	Sereno et al. 2013
<i>Adeopapposaurus mognai</i>	Sauropodomorpha	Early Jurassic	187.7	Martinez 2009
<i>Plateosaurus</i> spp.	Sauropodomorpha	late Norian-Rhaetian	209.65	Yates 2003
<i>Melanorosaurus readi</i>	Sauropodomorpha	middle Norian-Rhaetian	214.15	Yates 2007
<i>Unaysaurus tolentinoi</i>	Sauropodomorpha	early Norian	222.45	Leal et al. 2004
<i>Pampadromaeus barberenai</i>	Sauropodomorpha	late Carnian-earliest Norian	228.95	Cabreira et al. 2011
<i>Jingshanosaurus xinwaensis</i>	Sauropodomorpha	Hettangian	200.3	Yates 2012
<i>Massospondylus carinatus</i>	Sauropodomorpha	Hettangian-Sinemurian	196.05	Gow et al. 1990
<i>Lesothosaurus diagnosticus</i>	Ornithischia	Hettangian-Sinemurian	196.05	Nesbitt 2011
<i>Heterodontosaurus tucki</i>	Ornithischia	Hettangian-Sinemurian	196.05	Norman et al. 2011
<i>Emausaurus ernsti</i>	Ornithischia	Toarcian	182.5	Haubold 1990

Table S2. List of additional taxa from the Middle and Late Jurassic and Cretaceous used to calculate ancestral shapes falling into the Early Jurassic in the present analyses with data of occurrences (in million of years) and sources of skull reconstructions.

Species	Clade	Age	Time	Source
<i>Dakosaurus andiniensis</i>	Crocodylomorpha	Tithonian-Berriasian	145.95	Pol and Gasparini 2009
<i>Isisfordia duncani</i>	Crocodylomorpha	Albian-Cenomanian	99.4	Salisbury et al. 2006
<i>Mahajangasuchus insignis</i>	Crocodylomorpha	Maastrichtian	69.05	Turner and Buckley 2008
<i>Sarcosuchus imperator</i>	Crocodylomorpha	Berriasian-Cenomanian	119.25	Sereno et al. 2001
<i>Montealtosuchus arrudacamposi</i>	Crocodylomorpha	Turonian-Santonian	88.75	Carvalho et al. 2007
<i>Leidyosuchus canadensis</i>	Crocodylomorpha	Campanian	77.1	Wu et al. 2001
<i>Hamadasuchus rebouli</i>	Crocodylomorpha	Albian-Cenomanian	103.25	Larsson and Sues 2007
<i>Kaprosuchus saharicus</i>	Crocodylomorpha	Cenomnianian	97.2	Sereno and Larsson 2009
<i>Notosuchus terrestris</i>	Crocodylomorpha	Santonian	84.95	Fiorelli and Calvo 2008
<i>Mariliasuchus amarali</i>	Crocodylomorpha	Campanian-Maastrichtian	74.8	Zaher et al. 2006
<i>Malawisuchus mwakasyungutiensis</i>	Crocodylomorpha	Aptian	119	Gomani 1997
<i>Gobiosuchus kielanae</i>	Crocodylomorpha	Campanian	77.1	Osmólska et al. 1997
<i>Araripesuchus wegneri</i>	Crocodylomorpha	Aptian-Albian	112.75	Sereno and Larsson 2009
<i>Simosuchus clarki</i>	Crocodylomorpha	Maastrichtian	69.05	Kley et al. 2010
<i>Anatosuchus minor</i>	Crocodylomorpha	Aptian-Albian	112.75	Sereno and Larsson 2009
<i>Campinasuchus dinizi</i>	Crocodylomorpha	Turonian-Santonian	88.75	Carvalho et al. 2011
<i>Scaphognathus crassirostris</i>	Pterosauria	Tithonian	148.55	Bennett 2014
<i>Monolophosaurus jiangi</i>	Theropoda	Callovian	164.8	Rauhut 2003
<i>Haplocheirus sollers</i>	Theropoda	Oxfordian	160.4	photo material by CF

<i>Guanlong wucaii</i>	Theropoda	Oxfordian	160.4	Xu et al. 2006a
<i>Sinraptor dongi</i>	Theropoda	Oxfordian	160.4	Currie and Zhao 1993
<i>Allosaurus fragilis</i>	Theropoda	Kimmeridgian-Tithonian	151.15	Loewen 2009
<i>Ceratosaurus nasicornis</i>	Theropoda	Kimmeridgian-Tithonian	151.15	Sampson and Witmer 2007
<i>Limusaurus inextricabilis</i>	Theropoda	Oxfordian	160.4	Xu et al. 2009
<i>Compsognathus longipes</i>	Theropoda	Tithonian	148.55	Peyer 2006
<i>Archaeopteyx lithographica</i>	Theropoda	Tithonian	148.55	Rauhut 2014
<i>Shunosaurus lii</i>	Sauropodomorpha	Bajocian-Callovian	166.9	Rauhut et al. 2011
<i>Mamenchisaurus youngi</i>	Sauropodomorpha	Oxfordian	160.4	Ouyang and Ye 2002
<i>Diplodocus spp.</i>	Sauropodomorpha	Kimmeridgian-Tithonian	151.15	Wilson and Sereno 1998
<i>Camarasaurus lentus</i>	Sauropodomorpha	Kimmeridgian-Tithonian	151.15	Wilson and Sereno 1998
<i>Giraffatitan brancai</i>	Sauropodomorpha	Kimmeridgian-Tithonian	151.15	Wilson and Sereno 1998
<i>Huayangosaurus taibaii</i>	Ornithischia	Bajocian-Callovian	166.9	Sereno and Dong 1992
<i>Stegosaurus stenops</i>	Ornithischia	Kimmeridgian-Tithonian	151.15	Sereno and Dong 1992
<i>Dysalotosaurus lettowvorbecki</i>	Ornithischia	upper Kimmeridgian	153.25	Hübner and Rauhut 2010
<i>Agilisaurus louderbacki</i>	Ornithischia	Bajocian-Callovian	166.9	Barrett et al. 2005
<i>Yinlong downsi</i>	Ornithischia	Oxfordian	160.4	Xu et al. 2006b
<i>Camptosaurus dispar</i>	Ornithischia	Kimmeridgian-Tithonian	151.15	Brill and Carpenter 2006
<i>Psittacosaurus mongoliensis</i>	Ornithischia	Lower Cretaceous	122.75	Sereno et al. 1988

Table S3. Additional taxa for time calibration with data of occurrences (in millions of years).

Species	Clade	Age	Time
<i>Noteosuchus colletti</i>	Rhynchosauria	Induan-early Olenekian	250.7
<i>Archosaurus rossicus</i>	Proterosuchidae	Changhsingian	253.15
<i>Dorosuchus neoetus</i>	Archosauriformes	Anisian	244.6
<i>Aetosauroides scagliai</i>	Aetosauria	late Carnian-earliest Norian	228.95
<i>Turfanosuchus dabanensis</i>	Gracilisuchidae	late Anisian	243.3
<i>Ticinosuchus ferox</i>	Suchia	late Anisian	243.3
<i>Ctenosauriscus koeneni</i>	Poposauroida	late Olenekian	248.2
<i>Orthosuchus stormbergi</i>	Crocodyliformes	Hettangian-Sinemurian	196.05
<i>Hsisosuchus dashanpuensis</i>	Crocodyliformes	Bajocian-Calloviaian	166.9
<i>Calsoyasuchus valliceps</i>	Crocodyliformes	Sinemurian-Pliensbachian	191
<i>Asilisaurus kongwe</i>	Ornithodira	late Anisian	243.3
<i>Pisanosaurus mertii</i>	Ornithischia	late Carnian-earliest Norian	228.95
<i>Eocursor parvus</i>	Ornithischia	middle Norian-Rhaetian	214.15
<i>Scelidosaurus harrisonii</i>	Ornithischia	Sinemurian	195.05
<i>Vulcanodon karibaensis</i>	Sauropodomorpha	Hettangian	200.3
<i>Camposaurus arizonensis</i>	Theropoda	early Norian	221.15
<i>Berberosaurus liassicus</i>	Theropoda	Pliensbachian-Toarcian	182.45
<i>Proceratosaurus bradleyi</i>	Theropoda	Bathonian	166.2

2. Description of landmarks and semi-landmarks

Table S4. Description of landmarks and semi-landmark description. Semi-landmarks (semi-LMs) are marked with an ‘S’ (Fig. S1).

LMs	Description
1	Most anterior point of the premaxilla along the tooth row.
2	Contact of the lateral wall of premaxilla and maxilla along the tooth row (thereby making it possible to capture the subnarial notches of <i>Heterodontosaurus</i> , <i>Protosuchus</i> and <i>Tawa</i>).
3	Contact between maxilla and jugal along the ventral margin of the skull.
4	Most posterior point of the lateral condyle of the quadrate (if the quadrate is covered by the quadratojugal, the most posterior point of the posteroventral corner of the quadratojugal is chosen).
5	The most posterodorsal point of the subnarial process of the premaxilla and the maxilla. (The position of this landmark in the reconstruction of <i>Yinlong</i> based on personal observations).
6	The most posterior point of the ascending process of the maxilla along the dorsal margin of the antorbital fenestra. If no antorbital fenestra is developed, the most anterodorsal contact between maxilla and lacrimal was marked.
7	The most posterior point of the jugal process of the maxilla along the ventral margin of the antorbital fenestra. If no antorbital fenestra is developed, the most posteroventral contact between the maxilla and lacrimal was marked (The position of this landmark in the reconstruction of <i>Allosaurus</i> based on personal observations of various specimens of <i>Allosaurus</i>).
8	The contact between jugal and lacrimal along the orbital margin (for <i>Azendohsaurus</i> , <i>Malawisuchus</i> , <i>Mariliasuchus</i> , <i>Protosuchus</i> and <i>Trilophosaurus</i> , the most anterior point of the jugal along the orbital margin was chosen as the lacrimal is excluded from the orbit. In contrast, for some phytosaurs the most ventral point of the lacrimal along the orbital margin was marked, as the jugal is excluded from the orbit. The position of the landmark in the reconstruction of <i>Scaphognathus</i> is based on Wellnhofer 1975).
9	Contact between jugal and postorbital along the orbital margin.
10	The most dorsal point of the postorbital along the orbital margin.
11	The contact between jugal and postorbital along the margin of the lateral temporal fenestra/opening. For <i>Simosuchus</i> we plotted the most dorsal contact of the jugal along the anterodorsal margin of the lateral temporal fenestra.
12	The ventral contact between postorbital and squamosal (This contact is usually located along the dorsal margin of the lateral temporal fenestra/opening, but is different in some rhynchosaurs, aetosaurs, <i>Dakosaurus</i> , <i>Postosuchus</i> , <i>Protosuchus</i> and <i>Yinlong</i>).
13	The dorsal contact between postorbital and squamosal.
14	Most ventral contact between the posterior process of the squamosal and quadrate.

15	Contact between jugal and quadratojugal along the ventral margin of the lateral temporal fenestra (For those taxa where the fenestra is ventrally open due to a reduction of the quadratojugal, the most posterior point of the posterior process of the jugal was marked. In the reconstruction of <i>Dysalotosaurus</i> , we plotted this landmark at the most posterior point of the jugal along the ventral margin of the lateral temporal fenestra).
S16-S17	Two semi-landmarks between LM1 and LM2 along the ventral margin of the premaxilla.
S18-S20	Three semi-landmarks between LM2 and LM3 along the ventral margin of the maxilla.
S21-S35	15 semi-landmarks between LM1 and LM14 along the dorsal margin of the skull
S36-S38	Four semi-landmarks between LM6 and LM7 along the anterior and posterior margin of the antorbital fenestra. In taxa lacking an antorbital fenestra, the semi-landmarks are placed along the suture contact of maxilla and lacrimal (Fig. S1).
S39-S43	Four semi-landmarks between LM8 and LM10 along the anterodorsal margin of the orbit.
S44-S45	Two semi-landmarks between LM10 and LM9 along the posterior margin of the orbit.
S46	One semi-landmark between LM8 and LM9 along the ventral margin of the orbit.
S47-S48	Two semi-landmarks between LM11 and LM15 along the anteroventral margin of the lateral temporal opening.
S49-S53	Five semi-landmarks between LM12 and LM14 along the ventral margin of the squamosal.

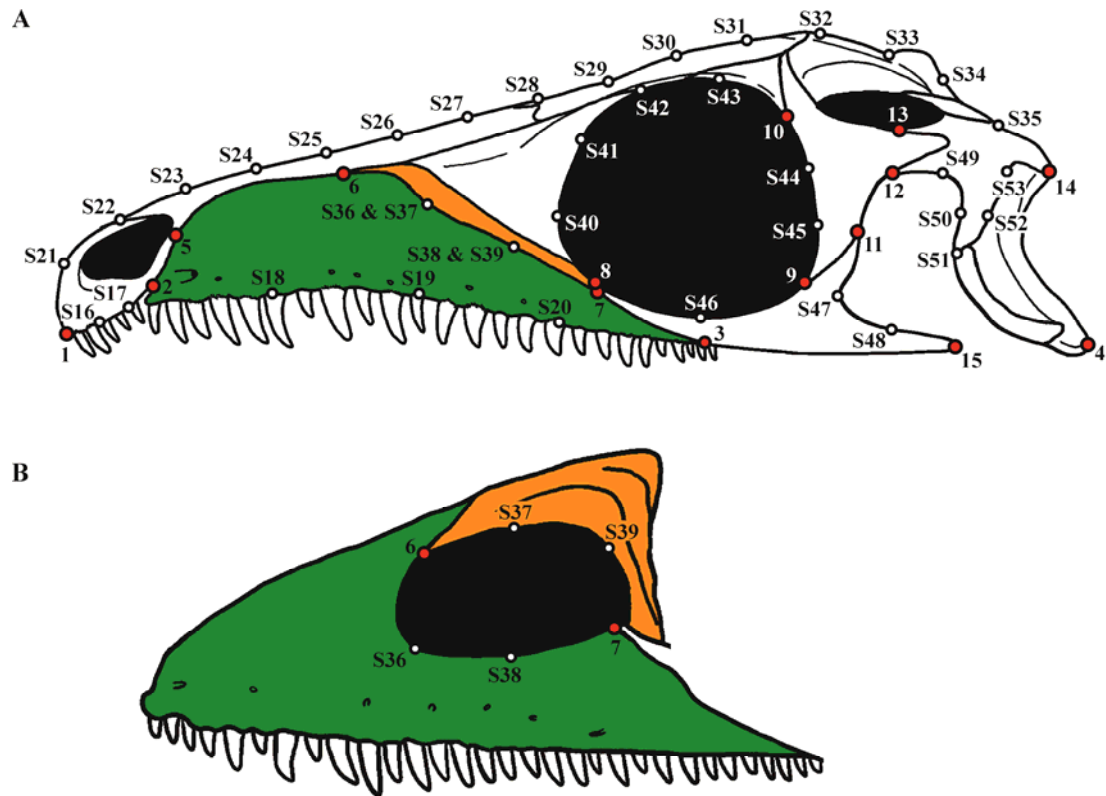


Figure S1. Distribution of landmarks and semi-landmarks. **(A)** Skull reconstruction of *Prolacerta broomi* in lateral view. Due to the absence of an antorbital fenestra the semi-landmarks S36 to S39 are placed along the suture contact of maxilla (green) and lacrimal (orange). **(B)** Reconstruction of maxilla (green) and lacrimal (orange) in anatomical position of *Proterosuchus fergusi* in lateral view showing the position of semi-landmarks S36 to S39 when an antorbital fenestra is present. All reconstructions are modified after Ezcurra and Butler (2015).

3. Phylogeny

To reconstruct ancestral shapes, we created two informal, time-calibrated supertrees based on recent literature. The main topology was based on Nesbitt (2011), but for one tree the position of phytosaurs were placed within crown Archosauria (Sereno 1991; Brusatte et al. 2010; Ezcurra 2016), while in the other phytosaurs are treated as non-archosaurian archosauromorphs following Nesbitt (2011). The sources of the phylogenetic positions of taxa not included in the analyses of Nesbitt (2011) are listed in Table S5.

Table S5. Sources for phylogenetic position of taxa included in the informal supertree.

Species	Clade	Source of Phylogeny
<i>Langobardisaurus pandolfii</i>	'Protorosauria'	Pritchard et al. 2015
<i>Protorosaurus speneri</i>	'Protorosauria'	Gottman-Quesada and Sander 2009
<i>Tanystropheus longobardicus</i>	'Protorosauria'	Ezcurra et al. 2014
<i>Prolacerta broomi</i>	Prolacertidae	Ezcurra et al. 2014
<i>Proterosuchus fergusi</i>	Proterosuchidae	Ezcurra et al. 2014
<i>Proterosuchus alexanderi</i>	Proterosuchidae	Ezcurra et al. 2014
<i>Proterosuchus goweri</i>	Proterosuchidae	Ezcurra et al. 2014
<i>Trilophosaurus buettneri</i>	Allokotosauria	Ezcurra et al. 2014
<i>Azendohsaurus madagaskarensis</i>	Allokotosauria	Nesbitt et al. 2013
<i>Bentonyx sidensis</i>	Rhynchosauria	Langer et al. 2010
<i>Hyperodapedon gordoni</i>	Rhynchosauria	Langer and Schultz 2000
<i>Hyperodapedon huxleyi</i>	Rhynchosauria	Hone and Benton 2008
<i>Hyperodapedon sanjuanensis</i>	Rhynchosauria	Hone and Benton 2008
<i>Mesosuchus browni</i>	Rhynchosauria	Hone and Benton 2008
<i>Rhynchosaurus articeps</i>	Rhynchosauria	Hone and Benton 2008
<i>Rhynchosaurus brodiei</i>	Rhynchosauria	Hone and Benton 2008
<i>Teyumbaita sulcognathus</i>	Rhynchosauria	Hone and Benton 2008
<i>Garjainia prima</i>	Erythrosuchidae	Pers. obs.
<i>Shansisuchus shansisuchus</i>	Erythrosuchidae	Gower and Sennikov 1996
<i>Gualosuchus reigi</i>	Proterochampsidae	Dilkes and Arcucci 2012
<i>Smilosuchus gregorii</i>	Phytosauria	Stocker 2010

<i>Brachysuchus megalodon</i>	Phytosauria	Stocker 2010
<i>Leptosuchus adamanensis</i>	Phytosauria	Stocker 2010
<i>Leptosuchus studeri</i>	Phytosauria	Stocker 2010
<i>Mystriosuchus planirostris</i>	Phytosauria	Parker and Irmis 2006
<i>Mystriosuchus westphali</i>	Phytosauria	Parker and Irmis 2006
<i>Nicrosaurus kapffi</i>	Phytosauria	Parker and Irmis 2006
<i>Pseudopalatus pristinus</i>	Phytosauria	Parker and Irmis 2006
<i>Gracilisuchus stipanicicorum</i>	Suchia	Butler et al. 2014
<i>Desmatosuchus smalli</i>	Aetosauria	Desojo et al. 2012
<i>Stagonolepis robertsoni</i>	Aetosauria	Desojo et al. 2012
<i>Stagonolepis olenkae</i>	Aetosauria	Desojo et al. 2012
<i>Neoaetosauroides engaeus</i>	Aetosauria	Desojo et al. 2012
<i>Aetosaurus ferratus</i>	Aetosauria	Desojo et al. 2012
<i>Revueletosaurus callenderi</i>	Aetosauria	Desojo et al. 2012
<i>Stenomyti huangae</i>	Aetosauria	Small and Martz 2013
<i>Dakosaurus andiniensis</i>	Crocodylomorpha	Bronzati et al. 2012
<i>Isisfordia duncani</i>	Crocodylomorpha	Bronzati et al. 2012
<i>Leidyosuchus canadensis</i>	Crocodylomorpha	Bronzati et al. 2012
<i>Pelagosaurus typus</i>	Crocodylomorpha	Bronzati et al. 2012
<i>Sarcosuchus imperator</i>	Crocodylomorpha	Bronzati et al. 2012
<i>Araripesuchus wegeneri</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Campinasuchus dinizi</i>	Crocodylomorpha	Pol et al. 2014
<i>Gobiosuchus kielanae</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Hamadasuchus rebouli</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Kaprosuchus saharicus</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Mahajangasuchus insignis</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Malawisuchus mwakasyungutiensis</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Mariliasuchus amarali</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Montealtosuchus arrudacamposi</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Notosuchus terrestris</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Simosuchus clarki</i>	Crocodylomorpha	Pol et al. 2014; Sertich and O'Connor 2014
<i>Anatosuchus minor</i>	Crocodylomorpha	Sertich and O'Connor 2014
<i>Eudimorphodon ranzii</i>	Pterosauria	Andres and Myers 2013
<i>Campylognathoides spp.</i>	Pterosauria	Andres and Myers 2013
<i>Dorygnathus banthensis</i>	Pterosauria	Andres and Myers 2013
<i>Scaphognathus crassirostris</i>	Pterosauria	Andres and Myers 2013
' <i>Syntarsus</i> ' <i>kayentakatae</i>	Theropoda	Sues et al. 2011
<i>Zupaysaurus rougieri</i>	Theropoda	Sues et al. 2011
<i>Monolophosaurus jiangi</i>	Theropoda	Carrano et al. 2012

<i>Allosaurus fragilis</i>	Theropoda	Carrano et al. 2012
<i>Sinraptor dongi</i>	Theropoda	Carrano et al. 2012
<i>Archaeopteryx lithographica</i>	Theropoda	Foth et al. 2014
<i>Compsognathus longipes</i>	Theropoda	Foth et al. 2014
<i>Guanlong wucaii</i>	Theropoda	Foth et al. 2014
<i>Haplocheirus sollers</i>	Theropoda	Foth et al. 2014
<i>Ceratosaurus nasicornis</i>	Theropoda	Pol and Rauhut 2012
<i>Limusaurus inextricabilis</i>	Theropoda	Pol and Rauhut 2012
<i>Adeopapposaurus mognai</i>	Sauropodomorpha	Martínez 2009
<i>Eoraptor lunensis</i>	Sauropodomorpha	Martínez et al. 2013
<i>Pampadromaeus barberenai</i>	Sauropodomorpha	Martínez et al. 2013
<i>Jingshanosaurus xinwaensis</i>	Sauropodomorpha	Yates 2007
<i>Massospondylus carinatus</i>	Sauropodomorpha	Yates 2007
<i>Melanorosaurus readi</i>	Sauropodomorpha	Yates 2007
<i>Plateosaurus</i> spp.	Sauropodomorpha	Yates 2007
<i>Unaysaurus tolentinoi</i>	Sauropodomorpha	Yates 2007
<i>Shunosaurus lii</i>	Sauropodomorpha	Wilson 2002
<i>Mamenchisaurus youngi</i>	Sauropodomorpha	Wilson 2002
<i>Diplodocus</i> spp.	Sauropodomorpha	Wilson 2002
<i>Camarasaurus lentus</i>	Sauropodomorpha	Wilson 2002
<i>Giraffatitan brancai</i>	Sauropodomorpha	Wilson 2002
<i>Lesothosaurus diagnosticus</i>	Ornithischia	Butler et al. 2010
<i>Heterodontosaurus tucki</i>	Ornithischia	Butler et al. 2010
<i>Emausaurus ernsti</i>	Ornithischia	Butler et al. 2010
<i>Huayangosaurus taibaii</i>	Ornithischia	Maidment et al. 2008
<i>Stegosaurus stenops</i>	Ornithischia	Maidment et al. 2008
<i>Dysalotosaurus lettowvorbecki</i>	Ornithischia	McDonald et al. 2010
<i>Agilisaurus louderbacki</i>	Ornithischia	Butler et al. 2010
<i>Yinlong downsi</i>	Ornithischia	Butler et al. 2010
<i>Camptosaurus dispar</i>	Ornithischia	Butler et al. 2010
<i>Psittacosaurus mongoliensis</i>	Ornithischia	Butler et al. 2010

The correlation between shape and phylogeny was tested using multivariate K statistics on the basis of Procrustes-fitted landmark coordinates using the program R (R Development Core Team) and the package geomorph (Adams and Otárola-Castillo 2013). This method estimates the strength of a phylogenetic signal in a data set in relation to a simulated Brownian motion model and was performed with 1,000 replications (Blomberg et al., 2003; Paradis, 2012; Adams, 2014). The strength of the phylogenetic signal is expressed as K and p-values. The test reveals that skull shape of archosauromorphs correlates significantly with phylogeny, while the position of phytosaurs has no impact on the signal (Table S6). However, the K-value < 1 implies that the skull shapes of the terminal taxa resemble each other less than expected under Brownian motion evolution (Blomberg et al., 2003). To confirm these results we performed an additional permutation test in MorphoJ (Klingenberg 2011), shuffling the Procrustes-fitted landmark coordinates of each taxon randomly across the tree (10,000 times), while the topology is held constant (Laurin 2004; Klingenberg and Gidaszewski 2010). As found using K statistics, cranial shape correlates significantly with phylogeny as the squared length of the original supertree (= tree length) occurs in over 95% of the randomly generated trees (Fig. S3; Table S6).

Table S6. Strength of the phylogenetic signal of the skull shape of Archosauromorpha.

	K	p-value	Tree length	p-value
Phytosauria as crown	0.079	0.001	3.431	<0.001
Phytosauria as stem	0.079	0.001	3.429	<0.001

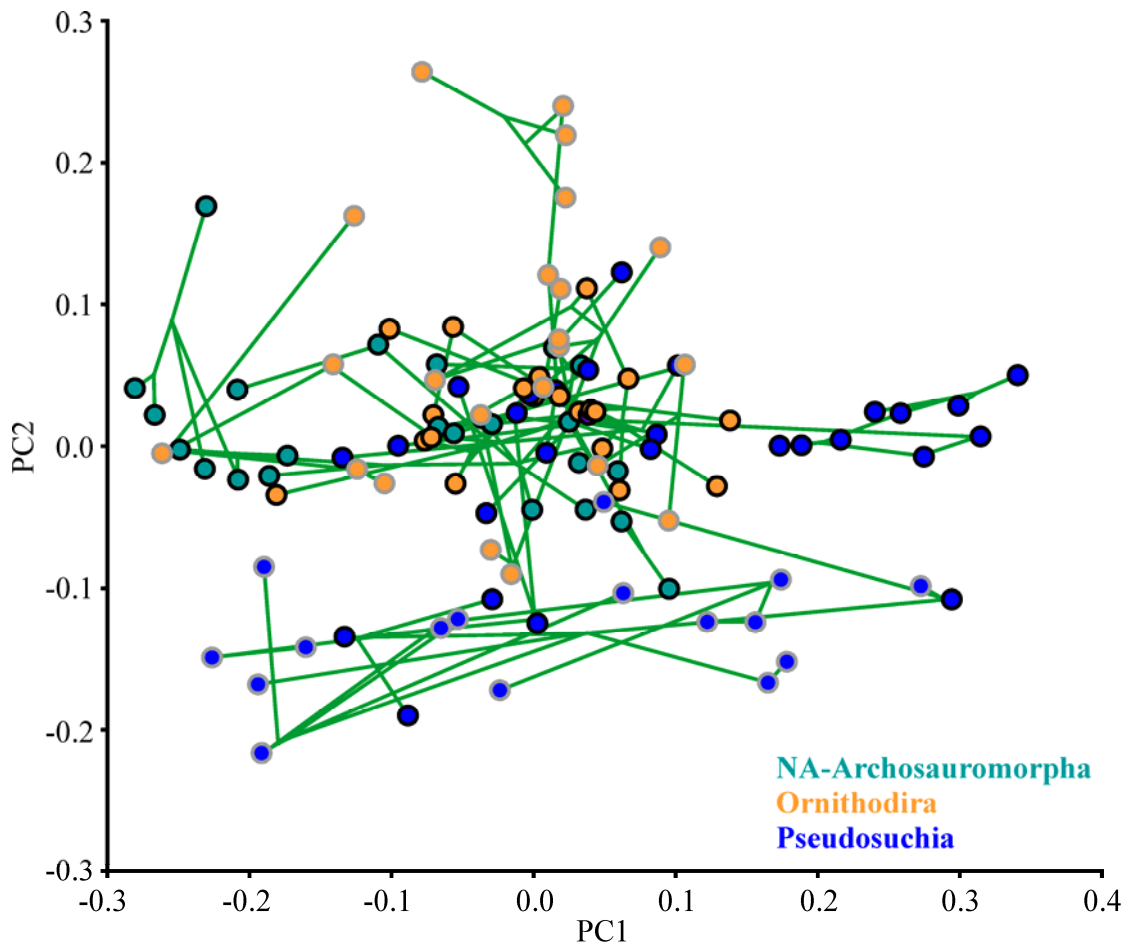


Figure S2. Morphospace of archosauromorphs, including post-Early Jurassic pseudosuchians (blue circle with grey outline) and ornithodirans (orange circle with grey outline), which were used specifically to trace ancestral shapes of archosaurs for the Early Jurassic period. Archosauromorphs living from the Permian to the end of Early Jurassic are marked with black outlines.

5. Disparity and NPMANOVA results

Table S7. Sum of variances of Archosauromorpha through time. The values for ornithodirans and dinosaurs are not affected by the phylogenetic position of phytosaurs. NA = non-archosaurian. Numbers in brackets show the sample size for each group per bin.

	all Archosauromorpha	Ornithodira	Dinosauria
PERMIAN (PE)	0.0023 (7)	-	-
EARLY TRIASSIC (ET)	0.0041 (20)	-	-
ANISIAN (ANI)	0.0217 (14)	-	-
LADINIAN (LAD)	0.0147 (11)	-	-
CARNIAN (CAR)	0.0415 (27)	0.0031 (9)	0.0031 (9)
NORIAN1 (NOR1)	0.0365 (17)	0.0035 (6)	0.0035 (6)
NORIAN2 (NOR2)	0.0362 (30)	0.0081 (11)	0.0068 (9)
HETTANGIAN (HET)	0.0118 (5)	-	-
SINEMURIAN (SIN)	0.0267 (14)	0.0222 (9)	0.0222 (9)
TOARCIAN (TOA)	0.0326 (8)	0.0121 (5)	-
Phytosaurs as crown group	NA-Archosauromorpha	Archosauria	Pseudosuchia
PERMIAN (PE)	0.0023 (7)	-	-
EARLY TRIASSIC (ET)	0.0053 (13)	0.0000 (7)	0.0000 (6)
ANISIAN (ANI)	0.0188 (12)	-	-
LADINIAN (LAD)	0.0207 (5)	0.0068 (6)	0.0068 (6)
CARNIAN (CAR)	0.0064 (6)	0.0176 (21)	0.0180 (12)
NORIAN1 (NOR1)	-	0.0290 (16)	0.0287 (10)
NORIAN2 (NOR2)	0.0282 (NOR1+NOR2) (3)	0.0345 (28)	0.0431 (17)
HETTANGIAN (HET)	-	0.0118 (5)	0.0001 (4)
SINEMURIAN (SIN)	-	0.0267 (14)	0.0089 (5)
TOARCIAN (TOA)	-	0.0326 (8)	0.0000 (3)
Phytosaurs as stem group	NA-Archosauromorpha	Archosauria	Pseudosuchia
PERMIAN (PE)	0.0023 (7)	-	-
EARLY TRIASSIC (ET)	0.0051 (14)	0.0000 (6)	0.0000 (5)
ANISIAN (ANI)	0.0188 (12)	-	-
LADINIAN (LAD)	0.0207 (5)	0.0068 (6)	0.0068 (6)
CARNIAN (CAR)	0.0815 (8)	0.0076 (19)	0.0044 (10)
NORIAN1 (NOR1)	0.0317 (8)	0.0106 (9)	0.0000 (3)
NORIAN2 (NOR2)	0.0398 (10)	0.0153 (20)	0.0171 (9)
HETTANGIAN (HET)	-	0.0118 (5)	0.0001 (4)
SINEMURIAN (SIN)	-	0.0267 (14)	0.0089 (5)
TOARCIAN (TOA)	-	0.0326 (8)	0.0000 (3)

Table S8. Statistical differences of sum of variances and morphospace position between subsequent time bins for all Archosauromorpha. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
PE-ET	0.0018	0.4041	6.9180	0.0495
ET-ANI	0.0176	0.0002	16.9400	0.0045
ANI-LAD	-0.0070	0.0717	3.85900	0.9180
LAD-CAR	0.0268	0.0870	0.9132	1.0000
CAR-NOR1	-0.0050	0.7068	4.6600	0.4860
NOR1-NOR2	-0.0004	0.9720	0.9306	1.0000
NOR2-HET	-0.0243	0.1264	8.2920	0.0765
HET-SIN	0.0149	0.0342	3.4680	1.0000
SIN-TOA	0.0059	0.6516	6.6270	0.0360

Table S9. Statistical differences of sum of variances and morphospace position between subsequent time bins for non-archosaurian Archosauromorpha. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Phytosauria as crown				
PE-ET	0.0030	0.2364	7.0960	0.0390
ET-ANI	0.0135	0.0011	17.3400	0.0015
ANI-LAD	0.0019	0.7939	3.7280	0.4110
LAD-CAR	-0.0143	0.3878	23.2200	0.0435
CAR-NOR (NOR1+NOR2)	0.0218	0.1881	4.8530	0.1830
Phytosauria as stem				
PE-ET	0.0028	0.2675	7.1040	0.0294
ET-ANI	0.0138	0.0015	19.6300	0.0021
ANI-LAD	0.0019	0.7950	3.7280	0.5712
LAD-CAR	0.0607	0.0287	2.1510	1.0000
CAR-NOR1	-0.0497	0.0001	7.0120	0.7371
NOR1-NOR2	0.0081	0.7470	0.4481	1.0000

Table S10. Sum of variances of non-archosauriform (NAF-) Archosauromorpha and non-archosaurian (NA-) Archosauriformes through time.

Phytosaurs as crown group	NAF-Archosauromorpha	NA-Archosauriformes
PERMIAN (PE)	0.0025	-
EARLY TRIASSIC (ET)	-	0.0026
ANISIAN (ANI)	0.0125	0.0126
LADINIAN (LAD)	-	0.0013
CARNIAN (CAR)	0.0064	-
Phytosaurs as stem group	NAF-Archosauromorpha	NA-Archosauriformes
PERMIAN (PE)	0.0025	-
EARLY TRIASSIC (ET)	-	0.0026
ANISIAN (ANI)	0.0125	0.0126
LADINIAN (LAD)	-	0.0012
CARNIAN (CAR)	0.0064	-
NORIAN1 (NOR1)	-	0.0022
NORIAN2 (NOR2)	-	0.0062

Table S11. Statistical differences of sum of variances and morphospace position between subsequent time bins for non-archosauriform (NAF-) Archosauromorpha and non-archosaurian (NA-) Archosauriformes when phytosaurs are members of the crown-group of Archosauria. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
NAF-Archosauromorpha				
PE- ANI	0.0100	0.0240	17.9200	0.0048
ANI-CAR	-0.0061	0.5579	16.9000	0.0069
NA-Archosauriformes				
ET-ANI	0.0100	0.0234	4.6460	0.0054
ANI-LAD	-0.0113	0.1972	7.1130	0.3048

Table S12. Statistical differences of sum of variances and morphospace position between subsequent time bins for non-archosauriform (NAF-) Archosauromorpha and non-archosaurian (NA-) Archosauriformes when phytosaurs are members of the stem-line of Archosauria. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
NAF-Archosauromorpha				
PE- ANI	0.0100	0.0271	17.9200	0.0048
ANI-CAR	-0.0061	0.5574	16.9000	0.0069
NA-Archosauriformes				
ET-ANI	0.0100	0.0148	4.5880	0.0350
ANI-LAD	-0.0113	0.1995	7.1130	1.0000
LAD -NOR1	0.0010	0.2452	59.4100	0.0920
NOR1-NOR2	0.0039	0.1104	1.8820	1.0000

Table S13. Statistical differences of sum of variances and morphospace position between subsequent time bins for Archosauria. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Phytosauria as crown				
ET-LAD	0.0067	0.0003	8.2230	0.1372
LAD-CAR	0.0108	0.5922	3.1740	1.0000
CAR-NOR1	0.0113	0.1035	4.8790	0.4620
NOR1-NOR2	0.0055	0.3742	0.8775	1.0000
NOR2-HET	-0.0226	0.1507	9.4540	0.0196
HET-SIN	0.0149	0.0367	3.4680	0.7643
SIN-TOA	0.0059	0.6574	6.6270	0.0280
Phytosauria as stem				
ET-LAD	0.0067	0.0013	6.8150	0.4592
LAD-CAR	0.0008	0.6504	4.5100	0.1596
CAR-NOR1	0.0030	0.1618	4.7660	0.0728
NOR1-NOR2	0.0047	0.2585	2.2570	1.0000
NOR2-HET	-0.0035	0.7053	14.0200	0.0056
HET-SIN	0.0149	0.0355	3.4680	0.7027
SIN-TOA	0.0059	0.6568	6.6270	0.0168

Table S14. Statistical differences of sum of variances and morphospace position between subsequent time bins for Pseudosuchia. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Phytosauria as crown				
ET-LAD	0.0068	0.0019	6.9330	0.4368
LAD-CAR	0.0112	0.6098	6.1220	0.1176
CAR-NOR1	0.0107	0.0921	4.5650	0.8427
NOR1-NOR2	0.0144	0.1099	1.2660	1.0000
NOR2-HET	-0.0430	0.0079	9.0340	0.0168
HET-SIN	0.0088	0.0180	9.3810	0.4956
SIN-TOA	-0.0089	0.6786	35.4500	0.4424
Phytosauria as stem				
ET-LAD	0.0068	0.001900	5.5630	0.4564
LAD-CAR	-0.0024	0.441700	9.2180	0.0224
CAR-NOR1	-0.0044	0.618500	22.4700	0.1148
NOR1-NOR2	0.0171	0.102700	5.2420	0.1596
NOR2-HET	-0.0170	0.069800	14.7400	0.0336
HET-SIN	0.0088	0.016000	9.3810	0.4760
SIN-TOA	-0.0089	0.900600	35.4500	0.5375

Table S15. Statistical differences of sum of variances and morphospace position between subsequent time bins for Ornithodira/Dinosauria. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Ornithodira				
CAR-NOR1	0.0004	0.8045	8.1730	0.0220
NOR1-NOR2	0.0046	0.0822	0.5507	1.0000
NOR2-SIN	0.0140	0.0299	3.7450	0.1870
SIN-TOA	-0.0100	0.2724	3.2080	0.2290
Dinosauria				
CAR-NOR1	0.0004	0.7908	8.1730	0.0114
NOR1-NOR2	0.0033	0.2235	0.7489	1.0000
NOR2-SIN	0.0154	0.0351	3.6580	0.1950

Table S16. Statistical differences of sum of variances and morphospace position between different groups within time bin when phytosaurs are crown-archosaurs.

Bold p-values represent significant results. NAF = non-archosauriform; NA = non-archosaurian.

Phytosauria as crown	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
NA-Archosauromorpha vs. Archosauria				
EARLY TRIASSIC	0.0053	0.0315	3.8020	0.0354
LADINIAN	0.0140	0.0200	2.3470	0.3189
CARNIAN	-0.0112	0.6621	45.2500	0.0010
NAF-Archosauromorpha vs. NA-Archosauriformes				
ANISIAN	-0.0001	0.9834	6.5960	0.0051
NA-Archosauromorpha vs. Pseudosuchia				
EARLY TRIASSIC	0.0053	0.0355	3.3630	0.0642
LADINIAN	0.0140	0.0149	2.3470	0.3231
CARNIAN	-0.0116	0.6686	50.1200	0.0010
NA-Archosauromorpha vs. Ornithodira				
CARNIAN	0.0033	0.7244	100.4000	0.0020
Pseudosuchia vs. Ornithodira				
CARNIAN	0.0149	0.4270	11.0200	0.0010
NORIAN1	0.0252	0.0002	8.0490	0.0168
NORIAN2	0.0349	< 0.0001	5.4060	0.0330
SINEMURIAN	-0.0133	0.1795	7.5870	0.0012
TOARCIAN	-0.0121	0.4856	22.2400	0.0190

Table S17. Statistical differences of sum of variances and morphospace position between different groups within time bin when phytosaurs are stem-archosaurs. Bold p-values represent significant results. NAF = non-archosauriform; NA = non-archosaurian.

Phytosaurs as stem	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
NA-Archosauromorpha vs. Archosauria				
EARLY TRIASSIC	0.0050	0.0433	3.0990	0.0849
LADINIAN	0.0140	0.0177	2.3470	0.3186
CARNIAN	0.0739	< 0.0001	13.1600	0.0020
NORIAN1	0.0211	0.1338	13.5700	0.0060
NORIAN2	0.0245	0.0058	17.1800	0.0010
NAF-Archosauromorpha vs. NA-Archosauriformes				
ANISIAN	0.0001	0.9870	6.5960	0.0044
NA-Archosauromorpha vs. Pseudosuchia				
EARLY TRIASSIC	0.0050	0.0555	2.7050	0.1503
LADINIAN	0.0140	0.0144	2.3470	0.3246
CARNIAN	0.0771	< 0.0001	8.9560	0.0420
NORIAN1	0.0317	0.4941	8.4390	0.2670
NORIAN2	0.0228	0.0286	11.7100	0.0180
NA-Archosauromorpha vs. Ornithodira				
CARNIAN	0.0784	0.0002	6.6580	0.0610
NORIAN1	0.0282	0.0452	10.6200	0.0460
NORIAN2	0.0317	0.0005	12.7700	0.0110
Pseudosuchia vs. Ornithodira				
CARNIAN	0.0013	0.3593	19.2600	0.0010
NORIAN1	-0.0035	0.4831	26.9500	0.1280
NORIAN2	0.0089	0.0502	6.0580	0.0010
SINEMURIAN	-0.0133	0.1766	7.5870	0.0009
TOARCIAN	-0.0121	0.4835	22.2400	0.0149

5. Additional results and discussion points

5.1. General disparity trend within archosauromorph cranium

The current study shows that after the end-Permian mass extinction, cranial disparity of archosauromorphs increased slowly during the Early Triassic, which is in agreement with a general delayed recovery of ecosystems and taxon diversity after the extinction event (Irmis and Whiteside 2012; Lau et al. 2016). However, the shift in morphospace (Table S8) already indicates an initial diversification of archosauromorphs starting in the Early Triassic. The Anisian peak, which corresponds to a shift in morphospace, is evidence of an abrupt radiation of archosauromorphs (including crown archosaurs), beginning in the Middle Triassic and continuing until the end of the Late Triassic (Nesbitt 2011, Sidor et al. 2013) leading to a diversification of cranial morphologies including taxa with long (e.g. Phytosauria, Coelophysidae, Thalattosuchia, Protochampsidae) and short (e.g. Rhynchosauria, Heterodontosauridae, *Lotosaurus*) snouts. When compared to each other, non-archosauriform archosauromorphs are similar in cranial disparity to non-archosaurian archosauriforms during the Anisian, but occupy different regions in morphospace (Table S16, S17), supporting a process of radiation during the Middle Triassic. This radiation corresponded also with an increase in body size (Sookias et al. 2012a,b) and reveals an ecological diversification into different niches and probable dietary preferences, including piscivory (e.g. Phytosauria, Proterochampsia), omnivory (basal Sauropodomorpha, Aetosauria), carnivory (e.g. Rautisuchidae, Theropoda) and herbivory (e.g. Rhynchosauria, Ornithischia) (see Butler et al. 2011; Nesbitt et al. 2013). The mass extinction at the end of the Triassic resulted in a decrease in taxonomic diversity, including the extinction of all stem line archosaurs and all non-crocodylomorph pseudosuchians, which in turn led to a decrease in cranial disparity.

During their coexistence, the cranial morphospace of non-archosaurian archosauromorphs and archosaurs overlaps during the Ladinian (this result is found with both phylogenetic positions of phytosaurs, Table S16, S17). However, this overlap is not unambiguous evidence for ecological competition between the two groups during this period, but could also result from a statistical artefact as the crown group members in this time bin tend not to show extremes of skull shape (e.g. Gracilisuchidae and various basal Loricata), while the stem line representatives include taxa with short and high (Allokotosauria) and long and flattened skulls (Protochampsia), resulting in similar medians (centroids) in morphospace. However, whether this overlap is a real signal needs to be tested in the future with more detailed analyses including multiple lines of evidence.

5.2. The effect of the phylogenetic position of Phytosauria

The disparity trajectories for non-archosaurian archosauromorphs are greatly affected by the phylogenetic position of Phytosauria. When phytosaurs are considered the sister-taxon of Archosauria (Nesbitt 2011), the cranial disparity of non-archosaurian archosauromorphs increases from the late Permian to the Carnian, in which the changes between the Ladinian and the Carnian are significant. After a Carnian peak their cranial disparity decreases significantly in the early Norian, but re-expands slightly in the late Norian, before the group goes extinct at the end of the Late Triassic (Table S9). In contrast, the cranial disparity of Archosauria increases from the Early Triassic until the late Norian. From the late Norian into the Hettangian cranial disparity decreases, and then it expands again until the Toarcian (Fig. S3, Table S13). The changes between the Hettangian and Sinemurian are significant. In this scenario, cranial disparity of non-archosaurian archosauromorphs is higher than that of

Archosauria throughout the interval over which they coexist, but only significantly higher from the Early Triassic to the Carnian (Table S17). Non-archosaurian archosauromorphs exhibit a significant shift in morphospace from the late Permian to the Early Triassic and from the Early Triassic to the Anisian (Table S9), while in Archosauria these shifts occur from the late Norian to the Hettangian and from the Sinemurian to the Toarcian (Table S13). When compared to each other, both groups are significantly separated from each other in morphospace over the entire Late Triassic (Fig. S4), but not in the Early and Middle Triassic (Table S17). In sum, if phytosaurs were stem-archosaurs, non-archosaurian archosauromorph disparity far exceeds that of Archosauria during the whole Triassic, before the sudden extinction of all non-crown taxa at the end of the Triassic. In addition, the cranial disparity of Pseudosuchia and Ornithodira would be relatively equal during the Late Triassic (Fig. S3), although both groups occupy different areas of morphospace (as found by Brusatte et al. 2008). In this scenario, the “true” radiation of crown archosaurs began following the end-Triassic extinction, precipitated by an increase of taxonomic and morphological diversity in Ornithodira. Thus, our view of the evolutionary radiation of Archosauria, pseudosuchians and ornithodirans in particular, is strongly affected by the inclusion or exclusion of phytosaurs within the crown. This in turn highlights the importance of phylogeny in understanding the early evolutionary history of Archosauria. As the most recent and taxonomically comprehensive (at least regarding stem-archosaurs) phylogenetic analysis favours the originally proposed relationship of phytosaurs as members of Pseudosuchia (Ezcurra 2016), the alternative disparity patterns of non-archosaurian archosauromorphs and archosaurs are presented in the main text. Nevertheless, as highlighted in the main text, the evolutionary patterns

described and discussed there are still valid for the paraphyletic group composed of non-archosaurian archosauromorphs to the exclusion of phytosaurs.

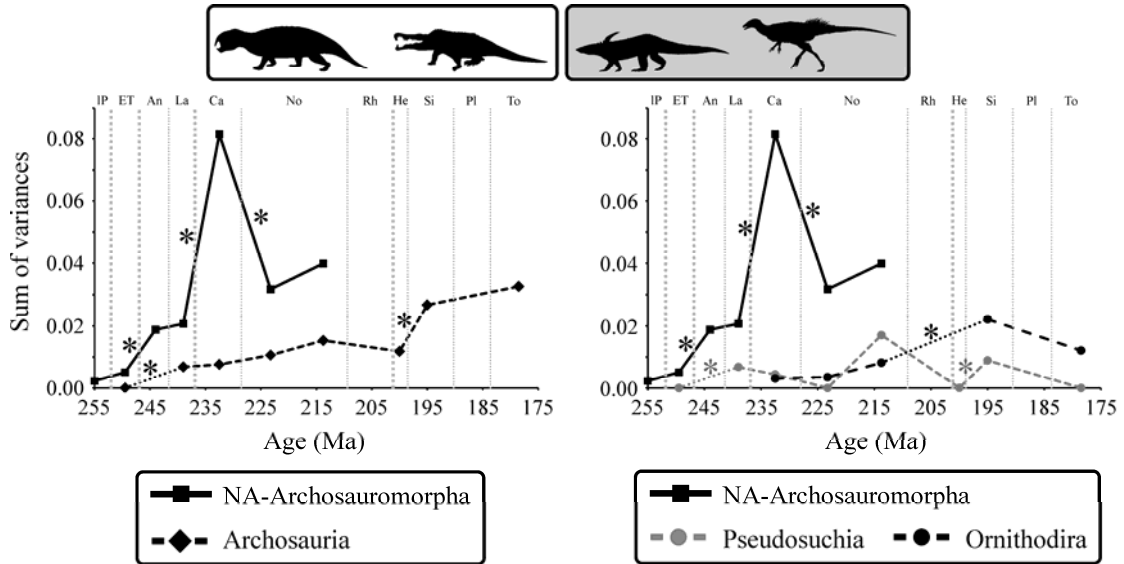


Figure S3. Disparity of archosauromorphs through time from the late Permian to the end of the Early Jurassic with phytosaurs as members of the stem group. Left: Temporal pattern of non-archosaurian archosauromorphs (solid line with black squares) and crown archosaurs (dashed line with black diamonds). Right: Temporal pattern showing non-archosaurian archosauromorphs (solid line with black squares) against pseudosuchians (dashed line with grey circles) and ornithodirans (dashed line with black circles). Significant changes between subsequent time bins are marked with an asterisk. Dotted lines mark missing time bins due to small sample sizes.

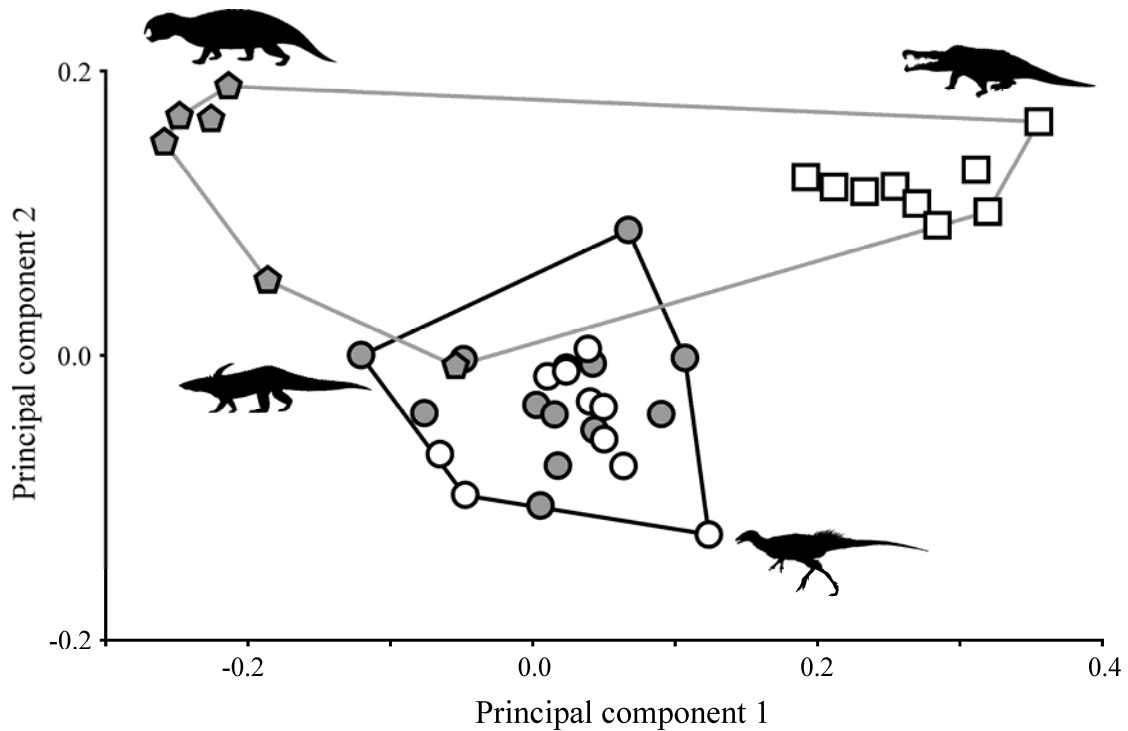


Figure S4. Two-dimensional morphospace of Late Triassic archosauromorphs showing the morphospace of non-archosaurian archosauromorphs (grey solid line with grey pentagons) including phytosaurs (white squares) and crown archosaurs (black solid line) with pseudosuchians (grey circles) and ornithodirans (white circles).

5.3. Cranial disparity trends within Ornithodira

Due to their poor record in earlier time bins, the oldest time interval for which we can estimate disparity for ornithodirans is the Carnian. From that interval, cranial disparity increases continuously until the Sinemurian, with both Ornithodira and Dinosauria showing significant shifts in morphospace from the Carnian to the early Norian (Fig. 4, S5). Disparity changes from the late Norian to Hettangian could not be estimated due to poor sampling in the later bin, but a significant increase is observed from the late Norian to the Sinemurian. In the Toarcian, cranial disparity decreases again (Table S15). When compared to each other, Pseudosuchia (including phytosaurs) and Ornithodira occupy significantly different areas in morphospace over the entire time

span (Table S16). When phytosaurs are excluded from crown-group archosaurs, however, the morphospace of pseudosuchians and ornithodirans overlaps in the early Norian (Table S17). The general differences in cranial morphospace over time between ornithodirans and pseudosuchians suggests that the two groups probably did not compete extensively with each other, e.g. for similar food resources. However, due to the poor fossil record of ornithodirans prior to the Late Triassic (Langer et al. 2013), nothing can be said about potential ecological overlap in previous time periods.

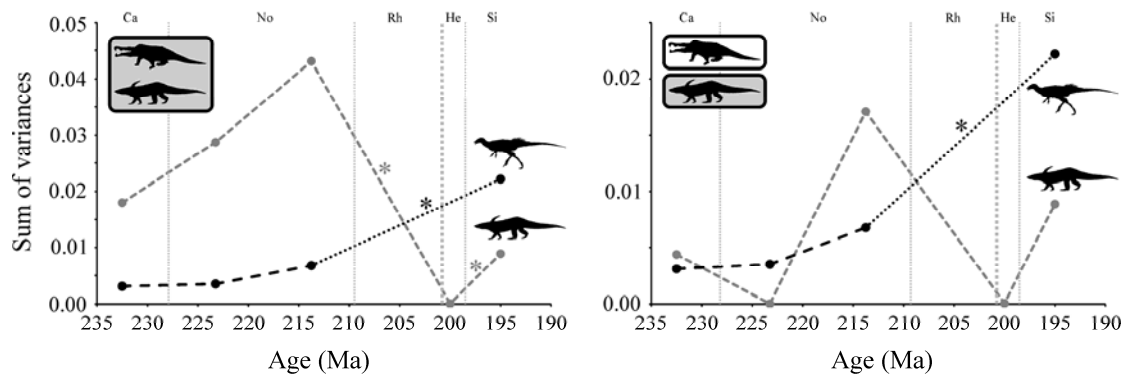


Figure S5. Temporal disparity of pseudosuchians (grey dashed line) and dinosaurs (black dashed line) from the Carnian to the end of the Early Jurassic. The left diagram shows the disparity trend when phytosaurs are members of the Pseudosuchia, while the right one shows the situation when phytosaurs are members of the stem-line.

5.4. The impact of ancestral shapes for disparity analyses

To study disparity changes through time we included the shapes of hypothetical ancestors to increase temporal resolution. To estimate the impact of the ancestors, we calculated the temporal disparity curves for all groups (when phytosaurs are members of crown Archosauria) on the basis of terminal taxa only and compared them with the results presented in the main text (Table S18-S23). Using only terminal taxa results in

slightly higher disparity. However, as the magnitude of sum of variance, the disparity metric used in this study, depends on the sample size, the higher disparity values are a mathematical artefact as the sample size is reduced due to the exclusion of ancestral shapes. The shapes of the disparity curves through time are generally similar for both approaches (Fig. S6), so that we assume that the basic trends described in this study are still valid. The inclusion of ancestral shapes furthermore allowed us to estimate disparity for earlier time bins and for those with low sample sizes. This is especially true for the Early Jurassic, where the fossil record of pseudosuchians and ornithodirans is generally low, complicating the estimation of statistically meaningful disparity values (Fig. S6).

Table S18. Sum of variances of Archosauromorpha (just terminal taxa) through time when phytosaurs are members of the crown. NA = non-archosaurian.

	all Archosauromorpha	Ornithodira	Dinosauria
EARLY TRIASSIC (ET)	0.0069	-	-
ANISIAN (ANI)	0.0246	-	-
LADINIAN (LAD)	0.0176	-	-
CARNIAN (CAR)	0.0527	0.0090	0.0090
NORIAN1 (NOR1)	0.0564	-	-
NORIAN2 (NOR2)	0.0369	0.0094	0.0081
SINEMURIAN (SIN)	0.0324	0.0288	0.0288
TOARCIAN (TOA)	0.0397	0.0210	-
Phytosaurs as crown group	NA-Archosauromorpha	Archosauria	Pseudosuchia
EARLY TRIASSIC (ET)	0.0069	-	-
ANISIAN (ANI)	0.0215	-	-
LADINIAN (LAD)	0.0237	0.0129	0.0129
CARNIAN (CAR)	0.0150	0.0240	0.0252
NORIAN1 (NOR1)	-	0.0346	0.0319
NORIAN2 (NOR2)	-	0.0351	0.0424
SINEMURIAN (SIN)	-	0.0324	-
TOARCIAN (TOA)	-	0.0397	-

Table S19. Statistical differences of sum of variances and morphospace position between subsequent time bins for all Archosauromorpha (just terminal taxa). Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
ET-ANI	0.0177	0.0047	4.1770	0.5796
ANI-LAD	-0.0070	0.2463	1.5380	1.0000
LAD-CAR	0.0352	0.2013	0.5349	1.0000
CAR-NOR1	0.0036	0.8671	1.4830	1.0000
NOR1-NOR2	-0.0194	0.2061	0.8348	1.0000
NOR2- SIN	-0.0046	0.7739	3.1540	0.8148
SIN-TOA	0.0074	0.7641	2.3690	1.0000

Table S20. Statistical differences of sum of variances and morphospace position between subsequent time bins for non-archosaurian Archosauromorpha (just terminal taxa) when phytosaurs are members of the crown. Bold p-values represent significant results.

Phytosauria as crown	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
ET-ANI	0.0146	0.0098	5.8550	0.0468
ANI-LAD	0.0021	0.8186	2.0420	0.7086
LAD-CAR	-0.0086	0.8475	9.0920	0.6312

Table S21. Statistical differences of sum of variances and morphospace position between subsequent time bins for Archosauria (just terminal taxa) when phytosaurs are members of the crown. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Phytosauria as crown				
LAD-CAR	0.0112	0.9163	1.1110	1.0000
CAR-NOR1	0.0106	0.4394	2.1960	1.0000
NOR1-NOR2	0.0005	0.9772	0.8255	1.0000
NOR2- SIN	-0.0028	0.8651	3.9240	0.2250
SIN-TOA	0.0074	0.7826	2.3690	0.9720

Table S22. Statistical differences of sum of variances and morphospace position between subsequent time bins for Pseudosuchia (just terminal taxa) when phytosaurs are members of the crown. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Phytosauria as crown				
LAD-CAR	0.0123	0.9812	2.0760	0.5316
CAR-NOR1	0.0067	0.5331	1.6940	1.0000
NOR1-NOR2	0.0105	0.4711	0.9249	1.0000

Table S23. Statistical differences of sum of variances and morphospace position between subsequent time bins for Ornithodira/Dinosauria (just terminal taxa) when phytosaurs are members of the crown. Bold p-values represent significant results.

	Sum of Variance		NPMANOVA	
	Difference	p-value	F	p-value
Ornithodira				
CAR-NOR2	0.0004	0.9543	2.1970	0.5634
NOR2-SIN	0.0194	0.1162	2.0490	0.7866
SIN-TOA	-0.0079	0.5706	0.9408	1.0000
Dinosauria				
CAR-NOR2	-0.0009	0.9643	2.5320	0.3273
NOR2-SIN	0.0207	0.1229	2.0490	0.3585

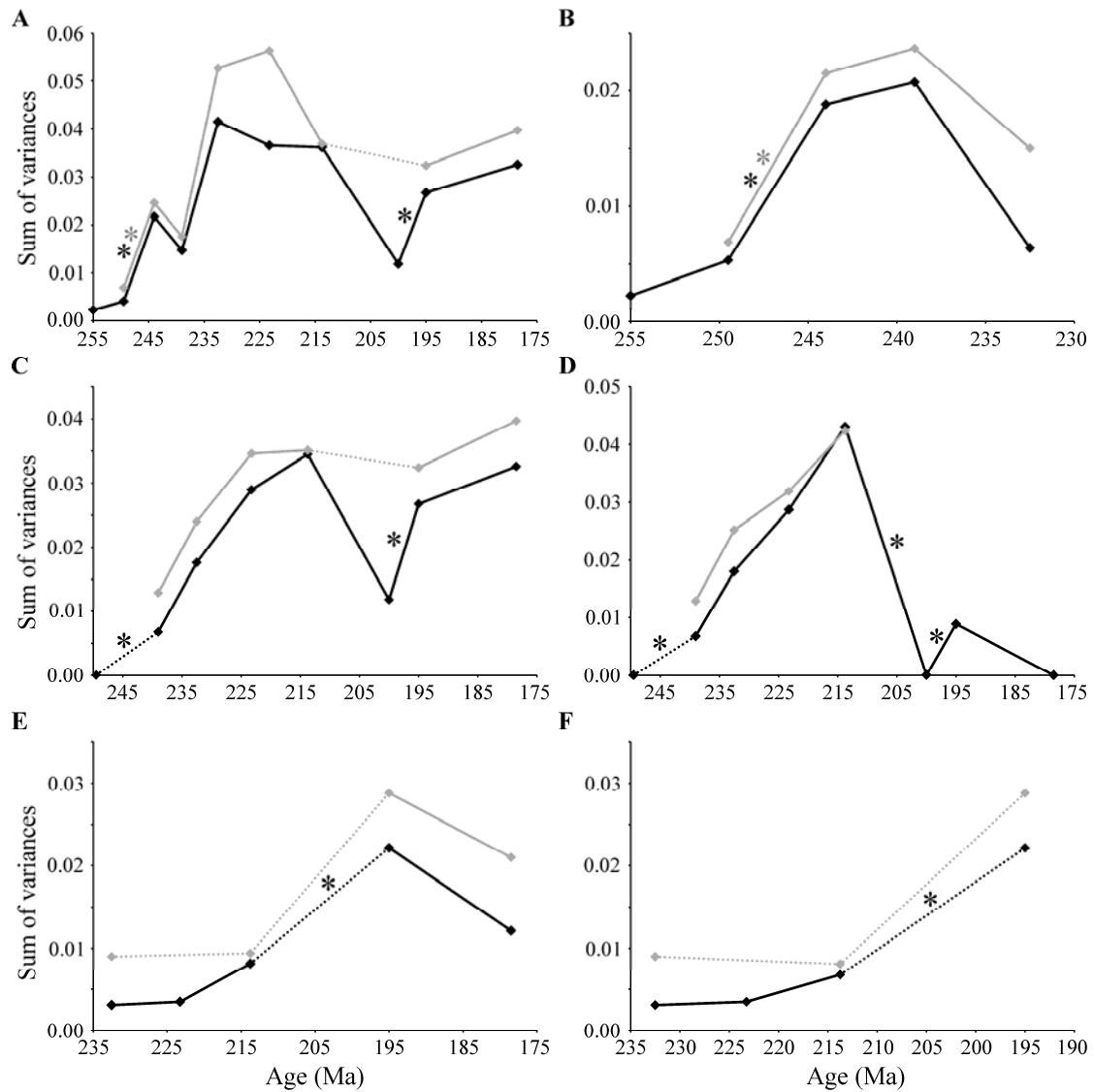


Figure S6. Comparison of disparity through time for various archosauromorph groups (when phytosaurs are crown archosaurs), if shapes of hypothetical ancestors were included (black line) or excluded (grey line). **(A)** Archosauromorpha. **(B)** Non-archosaurian Archosauromorpha. **(C)** Archosauria. **(D)** Pseudosuchia. **(E)** Ornithodira. **(F)** Dinosauria. Significant changes between subsequent time bins are marked with an asterisk. Dotted lines mark missing time bins due to small sample sizes.

5.5. The impact sample size for disparity analyses

To test the impact of sample size on the Sum of Variance disparity values recovered for each bin we performed Spearman's rank-order correlation tests and ordinary least squares (OLS) and generalized least squares (GLS) regression analyses with a first-order autoregressive model. Spearman's rank-order correlation test is a linear correlation test based on ranks, in which the r_s coefficient describes the strength of the correlation. This coefficient ranges from -1 to 1, in which $r_s = 0$ indicates no correlation (Hammer & Harper 2006). This test was performed in PAST (Hammer et al. 2001). While OLS estimates the strength of serial correlation between two variables by minimizing the sum of squares from a 'random' error (Hammer & Harper 2006), GLS uses maximum likelihood to correct for non-independence between adjacent points (Hansen 2007). Strength of correlation is given in form of R^2 for OLS and ϕ (dispersion parameter) and a correlation parameter for GLS. P-values indicate how significantly different the estimate slopes are from zero. All regression analyses were performed in R (R Development Core Team 2011), in which GLS was performed using the *gls()* function of the package 'nlme' (Pinheiro et al. 2016).

The majority of disparity curves show a weak correlation with sample size in the GLS regressions, but these correlations are significant only for all Archosauromorpha and Pseudosuchia (when phytosaurs are member of the crown). The latter result is also supported as significant by OLS and Spearman's correlation tests, while all other comparisons were non-significant. The correlations found for Archosauromorpha and Pseudosuchia might indicate that changes in disparity could be partly driven by sample size, and thus representing an artefact of variation in fossil record sampling through time. On the other hand, it could alternatively indicate that for these groups cranial disparity and species diversity are linked with each other,

indicating weak constraints on cranial disparity (see Wesley-Hunt 2005). Further discussion of this point is provided in the main text.

Table S24. Results of ordinary least squares (OLS) and generalised least squares (GLS) regressions, and Spearman’s correlation of skull shape disparity and sample size per bin. Values in brackets show the p-value of the slope, in which bold values indicate a significant result.

	OLS		GLS			Spearman’s
	Slope	R ²	Slope	φ	Correlation	r _s
all Archosauromorpha	324.0 (0.097)	0.3059	294.3 (0.010)	-0.1579	-0.8800	0.596 (0.069)
Ornithodira	28.1 (0.885)	0.0082	30.9 (0.877)	0.0502	-0.7960	-0.026 (0.933)
Dinosauria	56.2 (0.754)	0.0606	184.3 (0.068)	-0.8980	-0.8260	0.5 (0.667)
Phytosaurs as crown group						
NA-Archosauromorpha	-25.6 (0.922)	0.0037	-27.3 (0.919)	0.4133	-0.6150	-0.500 (0.450)
Archosauria	410.0 (0.119)	0.3555	410.7 (0.119)	0.0051	-0.8720	0.664 (0.093)
Pseudosuchia	292.2 (0.001)	0.8529	294.3 (0.000)	-0.4280	-0.7870	0.915 (0.004)
Phytosaurs as stem group						
NA-Archosauromorpha	-16.8 (0.761)	0.0202	-20.9 (0.702)	-0.0383	-0.7730	0.018 (0.987)
Archosauria	80.2 (0.732)	0.0210	46.9 (0.783)	-0.3834	-0.8410	0.323 (0.433)
Pseudosuchia	272.4 (0.088)	0.4089	261.5 (0.117)	-0.1276	-0.7060	0.639 (0.088)

5.6. The age of the Chañares Formation

During the writing of this manuscript, Marsicano et al. (2015) published the first radioisotopic dates for the Argentinean Chañares Formation (Ischigualasto-Villa Unión Basin). This unit was historically considered to be Ladinian (Rogers et al., 2001) or Ladinian–earliest Carnian in age (Desojo et al., 2011) based on biostratigraphical evidence and absolute dating of overlying formations. The dates published by Marsicano et al. (2015) are based on chemical abrasion thermal ionization mass spectrometry (CA-TIMS) of U–Pb zircons from two different stratigraphic layers that contain tuff in the lower member of the formation. These

dates (236.1 ± 0.6 Ma and 233.7 ± 0.4 Ma, respectively) indicate that most of the formation is early Carnian and not Ladinian, but since the Ladinian-Carnian boundary occurs at ca. 237 Ma (Gradstein et al., 2012) the lowermost portion of the unit could still be uppermost Ladinian in age. This new date for the Chañares Formation has an impact on the binning of three taxa used in our study: *Gracilisuchus stipanicorum*, *Chanaresuchus bonapartei* and *Gualosuchus reigi*. These three species occur within the first 7–30 metres of the unit and thus are positioned very close to the Ladinian–Carnian boundary (MDE pers. obs.). As a result, the Ladinian–earliest Carnian age used here for these taxa is still valid.

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