On-line Supplementary Data 1 – Character List

The character list used in the phylogenetic analysis has been compiled from a comprehensive list of published sources that reflect the broad scope of the terminal taxa: Brinkman and Eberth 1983, Benton 1985, Reisz 1986, Heaton and Reisz 1986, Gauthier *et al.* 1988, Carroll and Currie 1991, Laurin 1991, Reisz *et al.* 1992, Wu and Chatterjee 1993, Laurin 1993, Modesto 1994, Dodick and Modesto 1995, Laurin and Reisz 1995, Modesto 1995, Berman *et al.* 1995, Gower and Sennikov 1996, deBraga and Rieppel 1997, Sidor and Hopson 1998, Reisz *et al.* 1998, Dilkes 1998, Rieppel 1999, Modesto 1999, Modesto *et al.* 2001, Reisz and Dilkes 2003, Anderson and Reisz 2004, Müller 2004, Modesto and Sues 2004, Reisz and Laurin 2004, Müller and Reisz 2005, Müller et *al.* 2006, Müller and Reisz 2006, Tsuji 2006, Maddin *et al.* 2006, Müller and Tsuji 2007, Modesto *et al.* 2007, Maddin *et al.* 2008, Reisz *et al.* 2009, Botha-Brink and Modesto 2009, Bickelmann *et al.* 2009, Sumida *et al.* 2010, Campione and Reisz 2010, Mazierski and Reisz 2010, Reisz *et al.* 2010, Reisz *et al.* 2011, Nesbitt 2011, Fröbisch *et al.* 2011, Tsuji *et al.* 2012, Benson 2012, Modesto *et al.* 2014, MacDougall and Reisz 2014, Reisz and Fröbisch 2014, Ezcurra *et al.* 2014, Klembara *et al.* 2014, Pritchard *et al.* 2015, Schoch and Sues 2015, Romano *et al.* 2015, Modesto *et al.* 2015, Ezcurra 2016, Piñeiro *et al.* 2016, Brocklehurst *et al.* 2016, Laurin and Piñeiro 2017, Spindler *et al.* 2018, Modesto *et al.* 2018, MacDougall *et al.* 2018.

We list below each character with notes on its derivation and optimisation, together with any comments on the interpretative issues that have some bearing on the past or current scoring. The institutional abbreviation and accession number indicate all specimens personally examined by DPF. Characters relating to the present study are prefixed ‘ch’; characters relating to referenced studies are prefixed ‘c’.

Cranial characters

1. Skull, antorbital-postorbital length ratio: antorbital part of skull (anterior margin of orbit to anteriormost extremity of skull) equal to or longer than the postorbital part (posterior margin of orbit to posteriormost extremity of skull) (0); postorbital part longer than antorbital part (1)

Modified from Laurin and Reisz (1995 c.32), Modesto (1995 c.17), deBraga and Rieppel (1997 c.19), Müller (2004 c.8), Reisz *et al.* (2010 c.6), Benson (2012 c.2), Modesto *et al.* (2015 c.47).

State 1 is present in caseasaurs (Maddin *et al.* 2008) and some captorhinids (e.g. *Protocaptorhinus pricei*, MCZ 1478, Clark and Carroll 1973 and *Romeria texana*, MCZ 1480, Clark and Carroll 1973). Due to the increased length resulting from the strong anterodorsal inclination of the posterior margin of the skull in *Varanodon*, this taxon is scored as (1), in accordance with Reisz *et al.* 2010.

Unambiguous: *Deltavjatia rossicus* (0to1), *Candelaria barbouri* (0to1), Caseasauria (0to1). DELTRAN: *Captorhinus aguti* + *Captorhinus laticeps* (0to1), *Protocaptorhinus pricei* (0to1), *Romeria* spp (0to1), *Varanodon agilis* (0to1). ACCTRAN: *Labidosaurikos meachami* + *Labidosaurus hamatus* (1to0), *Reiszorhinus olsoni* (1to0), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Varanodon agilis* + *Watongia meieri* (0to1)

2. Skull, shape of antorbital region: mediolaterally broad, nasal largely dorsal element (0); mediolaterally narrow and dorsoventrally tall, nasal has nearly vertical contribution to snout (1)

From Modesto (1994 c.9), Reisz *et al.* (1998 c.12), Reisz and Dilkes (2003 c.12), Maddin *et al.* (2006 c.43), Reisz *et al.* (2010 c.5), Benson (2012 c.3), Spindler *et al.* (2018 c.4).

State (1) is considered as a synapomorphy of 'eupelycosaur'-grade synapsids, i.e. non-therapsid synapsids excluding caseasaurs (Reisz 1986, Kemp 2005, Brocklehurst *et al.* 2016).

Unambiguous: Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). DELTRAN: Mycterosaurinae + Varanodontinae (0to1), *Archaeovenator hamiltonensis* (0to1). ACCTRAN: Varanopidae (0to1), *Orovenator mayorum* (1to0)

3. Skull, extensive dermal sculpturing of skull roof: present (0), absent or weakly developed (1)

Modified from Laurin and Reisz (1995 c.38), Reisz *et al.* (2007 c.38), Maddin *et al.* (2008 c.48), Reisz *et al.* (2009 c.1), Benson 2012 (c.11), Tsuji *et al. (*2012 c.38), MacDougall and Reisz (2014 c.54).

This character describes the widely distributed pattern of pits, grooves and ridges found on the skull roof. A binary version of this character was adopted by MacDougall and Reisz 2014 (c.54), establishing the presence/absence of dermal sculpturing, with a new character to describe the nature of the sculpturing (MacDougall and Reisz 2014 c.55), and modified versions of these characters are included in the present study (the present character and ch.4 below). This character should not be confused with the presence or absence of circumorbital ornamentation in the form of tuberous ridges (ch.68 and ch.83 below).

Unambiguous: Procolophonoidea (0to1), Parareptilia except Mesosauridae and Bolosauria (1to0), *Thuringothyris mahlendorffae* (0to1), Diadectomorpha (0to1), *Vaughnictis smithae* (0to1), *Ophiacodon* spp (0to1). DELTRAN: Varanopidae +

Neoreptilia (0to1), Sphenacodontia except *Haptodus* (0to1), *Edaphosaurus boanerges* (0to1), *Hylonomus lyelli* (0to1), *Araeoscelis* spp (0to1). ACCTRAN: Reptilia except Captorhinidae (0to1), *Haptodus garnettensis* (1to0), Sphenacodontia + Edaphosauridae (0to1), 'protorothyridids' except *Hylonomus* (1to0), *Petrolacosaurus kansensis* (1to0)

4. Skull, dermal sculpturing, if present: composed of ridges and pits arranged in a honeycomb pattern (0); an irregular distribution of rounded pits (1); anastomosing narrow grooves and low ridges (2); deep pits with prominently raised knobs (3); inapplicable, sculpturing absent or weakly developed (-)

Modified from Laurin and Reisz (1995 c.38), Dodick and Modesto (1995 c.25), MacDougall and Reisz (2014 c.55), Reisz and Fröbisch (2014 c.48).

Unambiguous: Ankyramorpha except Lanthanosuchoidea (2to3), *Ennatosaurus tecton* (1to2), Caseasauria (2to1). DELTRAN: Lanthanosuchoidea (2to1), Reptilia except Captorhinidae (0to2), *Gephyrostegus bohemicus* (0to3), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to2). ACCTRAN: Ankyramorpha (2to1), Captorhinidae (2to0), Amniota + Diadectomorpha (0to2), *Gephyrostegus bohemicus* (0to3)

5. Skull, posterior margin in dorsal view: roughly straight (0); with a single, median embayment (1); embayed bilaterally (2)

Modesto (1999 c.125), Tsuji (2006 c.41), Modesto *et al.* (2015 c.58).

Unambiguous: *Nyctiphruretus* + Procolophonoidea (1to0), Neoreptilia (2to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (2to1), Amniota (1to2), *Pantelosaurus saxonicus* (1to2), Sphenacodontia + Edaphosauridae (2to1), *Hylonomus lyelli* (2to0). DELTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (1to0), *Protocaptorhinus pricei* (2to0), *Reiszorhinus olsoni* (2to0), Diadectomorpha (0to1). ACCTRAN: Bolosauria (1to0), *Romeria* spp (0to2), Captorhinidae except *Euconcordia* and *Thuringothyris* (2to0), Amniota + Diadectomorpha (0to1)

6. Teeth, distal recurvature of marginal teeth: present (0); absent (1)

Modified from Reisz *et al.* (1998 c.1), Maddin *et al. (*2008 c.67), Benson (2012 c.41), Reisz and Fröbisch (2014 c.67), Spindler *et al. (*2018 c.99).

In the present study, recurvature of the marginal teeth is defined as the apex of the tooth being situated distal to the distal margin of the crown base. When character state (0) is present the distal margin appears concave in lateral view. Character state (1) is scored in taxa possessing marginal teeth that that have a dorsoventrally straight distal margin in lateral view, even when a dorsoventrally convex mesial margin is present. A slight distal recurvature of the marginal dentition (state 0) is present in diadectomorphs (e.g. *Tseajaia*, Moss 1972 on dentary teeth only; *Limnoscelis*, Berman *et al.* 2010), *Seymouria* and *Gephyrostegus* (Klembara *et al.* 2005, 2014). Recurvature of marginal teeth (state 0) is also present in many early amniotes groups, including ophiacodontids, sphenacodontians, mycterosaurines, varanodontines, neodiapsids and some parareptiles.

Unambiguous: *Claudiosaurus germaini* (0to1), *Eudibamus cursoris* + *Belebey vegrandis* (0to1), *Deltavjatia rossicus* (0to1), *Colobomycter pholeter* (0to1), *Mesosaurus tenuidens* (0to1), *Reiszorhinus olsoni* (1to0), Amniota (0to1), *Vaughnictis smithae* (1to0), Ophiacodontidae except *Echinerpeton* (1to0). DELTRAN: *Procolophon trigoniceps* (0to1), *Nyctiphruretus acudens* (0to1), Varanopidae + Neoreptilia (1to0), Sphenacodontidae + *Cutleria wilmarthi* (1to0), *Haptodus garnettensis* (1to0), (1to0). ACCTRAN: Owenettidae (1to0), *Nyctiphruretus* + Procolophonoidea (0to1), Diapsida (1to0), *Pantelosaurus saxonicus* (0to1), Sphenacodontia (1to0), *Araeoscelis* spp (0to1)

7. Teeth, distal recurvature of marginal teeth, if present: slight to moderate (0); strong (1); inapplicable, distal recurvature absent (-)

Modified from Reisz *et al.* (1998 c.1), Maddin *et al. (*2008 c.67), Ezcurra *et al. (*2014 c.2), Benson (2012 c.41), Spindler *et al. (*2018 c.100).

Strong recurvature of the margin dentition (state 1) is present in mycterosaurines, varanodontines and archosauromorphs. In all other taxa scored as state (0) in ch.6 above, the recurvature is slight to moderate (state 0)

Unambiguous: Mycterosaurinae + Varanodontinae (0to1), Archosauromorpha (0to1).

8. Teeth, marginal dentition, cutting edges (carinae) on the mesial and distal surfaces: absent or only present distally (0); present (1)

From Reisz *et al. (*1992 c.58), Laurin (1993 c.64), Berman *et al. (*1995 c.66), Modesto (1995 c.2), Maddin *et al. (*2006 c.3); Mazierski and Reisz (2010 c.2), Fröbisch *et al.* (2011 c.50).

Unambiguous: Mycterosaurinae + Varanodontinae (0to1), *Macroleter poezicus* (0to1), *Colobomycter pholeter* (0to1), *Euconcordia cunninghami* (0to1), *Limnoscelis paludis* (0to1), Sphenacodontidae + *Cutleria wilmarthi* (0to1), Edaphosauridae (0to1). DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1)

9. Teeth, serrations on crown of marginal teeth: absent (0); present (1)

Modified from Gauthier *et al.* (1988 c.108), Modesto *et al. (*2001 c.32), Reisz and

Dilkes (2003 c.32), Campione and Reisz (2010 c.3), Ezcurra (2014 c.3).

Character state 1 is present in *Dimetrodon* (Romer and Price 1940), *Edaphosaurus* (Modesto 1995), *Mesenosaurus*, Reisz and Berman 2001) and *Proterosuchus* (Ezcurra *et al. 2*013). Serrations are present in the ophiacodontid *Archaeothyris*, although they are found only on the lingual surface of the anterior maxillary teeth (Reisz 1972).

Unambiguous: *Proterosuchus* spp (0to1), *Archaeothyris florensis* (0to1), *Dimetrodon* spp (0to1). DELTRAN: *Edaphosaurus boanerges* (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1). ACCTRAN: Mycterosaurinae (0to1), Edaphosauridae (0to1)

10. Teeth, lateral compression of marginal dentition: only apicially or nowhere (0); over two-thirds of tooth (1)

Modified from Reisz (1998 c.1), Reisz and Dilkes (2003 c.1), Reisz *et al. (*2010 c.4), Benson (2012 c.40), Ezcurra (2014 c.4).

Extensive labiolingual compression of the marginal dentition is present in derived mycterosaurines and in archosauromorphs. It is also present in the captorhinid *Reiszorhinus* (Sumida *et al. 2*010) and the sphenacodontid *Dimetrodon* (Romer and Price 1940).

Unambiguous: Mycterosaurinae + Varanodontinae (0to1), *Deltavjatia rossicus* (0to1), *Labidosaurus hamatus* (0to1), *Reiszorhinus olsoni* (0to1). DELTRAN: Archosauromorpha (0to1), *Dimetrodon* spp (0to1), *Cutleria wilmarthi* (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontidae + *Cutleria wilmarthi* (0to1)

11. Teeth, multiple apical cusps on marginal dentition: absent (0); present (1)

Modified from Maddin *et al. (*2008 c70), Reisz *et al. (*2009 c.21), Benson (2012 c.44), Reisz and Fröbisch (2014 c.70).

Unambiguous: *Deltavjatia rossicus* (0to1), Caseidae (0to1)

12. Premaxilla, number of teeth: five or more (0); four or fewer (1)

Carroll and Currie (1991 c.27), Berman *et al. (*1995 c.70), Modesto *et al. (*2001 c.2), Reisz and Dilkes (2003 c.41) Reisz *et al. (*2010 c.8), Benson (2012 c.17), Ezcurra (2014 c.8), Spindler *et al. (*2018 c.17).

Unambiguous: *Deltavjatia rossicus* (0to1), *Procolophon trigoniceps* (0to1), Ankyramorpha except Lanthanosuchoidea (1to0), Parareptilia except Mesosauridae

(0to1), *Captorhinus aguti* (0to1), *Thuringothyris mahlendorffae* (0to1), Diadectomorpha (0to1), Caseasauria (0to1), *Archaeovenator hamiltonensis* (0to1), *Aerosaurus wellesi* (0to1), *Mycterosaurus longiceps* (0to1). DELTRAN: *Youngina capensis* (0to1), *Dimetrodon* spp (0to1), *Cutleria wilmarthi* (0to1).ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontidae + *Cutleria wilmarthi* (0to1)

13. Premaxilla, orientation of ascending (supranarial) process in respect to the marginal tooth row of the premaxilla: subvertical at base, then slopes posterodorsally (0); slopes anterodorsally, overhanging tooth row ('rostral process' present) (1); slopes posterodorsally at an angle < 75° (2)

Modified from Brinkman and Eberth (1983 c.5), Reisz (1986 table 3a), Reisz and Dilkes (2003 c.51), Maddin *et al. (*2006 c.6), Maddin *et al. (*2008 c.1), Benson (2012 c.14), Spindler *et al. (*2018 c.16).

In previous studies character state (1) has been has been scored as present in caseasaurs and the diadectomorph *Limnoscelis* (Maddin 2008, Benson 2012, Spindler *et al. 2*018). Spindler *et al. (*2018) also scored this state for *Tseajaia*, although we consider this to be ambiguous given the compression of the snout and the displacement of the anterior premaxillary tooth (Moss 1972). A rostral process of the premaxilla (state 1) has been acquired independently in *Orovenator* and *Procolophon* (Cisneros 2008, Ford and Benson 2018). Langston and Reisz (1981) argued that a slight anterior slope (equivalent to a 'rostral process' in other taxa) of the premaxilla in *Aerosaurus wellesi* was due to post-mortem distortion. Brinkman and Eberth (1983) disagreed with this view, suggesting this feature was present in both *Aerosaurus* and *Varanops*. Later studies have been consistent in scoring the rostral process as absent in one or both these taxa (Reisz and Dilkes 2003, Maddin *et al. 2*008, Benson 2012, Spindler *et al. 2*018). Close examination of *Varanops* during the present study (MCZ 1961) confirms that a slight anterodorsal inclination of the premaxilla is present. We also concur with Brinkman and Eberth (1983) in that there is no clear evidence for distortion of the premaxilla in *Aerosaurus*. Consequently both taxa are scored as (1) in the present study. An acute posterodorsal slope of premaxilla, state (2), is an autapomorphy of derived ophiacodontids (e.g. *Varanosaurus*, FMNH PR 1670, Berman *et al.*1995 and *Ophiacodon,* MCZ 1366).

Unambiguous: *Procolophon trigoniceps* (0to1), Caseasauria (0to1), *Orovenator mayorum* (0to1). DELTRAN: *Limnoscelis paludis* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2), *Varanops brevirostris* (0to1), *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1), Diadectomorpha (0to1), Ophiacodontidae (0to2), *Varanodon agilis* + *Watongia meieri* (1to0)

14. Premaxilla, subnarial process excludes maxilla from margin of external naris or septomaxilla: absent (0); present (1)

Modified from Reisz *et al. (*2009 c.19), Benson (2012 c.16).

In the current taxon list *Tseajaia*, eothyridids, archosauromorphs and *Procolophon* possess a posterodorsal spur of the subnarial process of the premaxilla, which prevents the maxilla from contacting the septomaxilla or participating in the external naris (state 1). This morphology is absent in all other taxa where known (state 0).

Unambiguous: Eothyrididae (0to1), Archosauromorpha (0to1), *Procolophon trigoniceps* (0to1), *Tseajaia campi* (0to1).

15. Premaxilla, posterior surface of subnarial process, if present: contacts the lacrimal only (0); contacts the nasal (1); inapplicable, subnarial process does not exclude maxilla from external naris or septomaxilla (-)

Modified from Gauthier *et al. (*1988 c.2), Berman *et al. (*1995 c.11), Modesto *et al.* (2001 c.3), Müller (2004 c.2), Reisz *et al. (*2009 c. 19), Reisz *et al. (*2010 c.12), Spindler *et al. (*2018 c.15).

In eothyridids and the diadectomorph *Tseajaia* a posterodorsal spur of the subnarial process of the premaxilla contacts the lacrimal only posterior to the external naris (state 0)(MCZ 1161, Reisz *et al. 2*009, Moss 1972). In archosauromorphs the posterodorsal spur of the subnarial process of the premaxilla contacts the nasal (state 1)(e.g. *Prolacerta*, Modesto and Sues 2004; *Proterosuchus*, Ezcurra and Butler 2015). A similar process is also present in *Procolophon* (Carroll and Lindsey 1985).

DELTRAN: Neoreptilia (0to1). ACCTRAN: Reptilia (0to1).

16. Premaxilla, supranarial (dorsal) process, extending posteriorly level with or beyond the posterior margin of the external naris: absent (0), present (1)

Modified from Reisz *et al.* (1992 c.5), Laurin (1993 c.2), Fröbisch *et al. (*2011 c.1).

An anteroposteriorly long dorsal process of the premaxilla is present in ophiacodontids (Berman *et al.*1995, Romer and Price 1940), *Mesenosaurus* (Reisz and Berman 2001), *Araeoscelis*, *Orovenator* and early neodiapsids (Carroll 1981, Reisz *et al.*1984, Ford and Benson 2018).

Unambiguous: *Proterosuchus* spp (0to1), *Claudiosaurus germaini* (0to1), *Araeoscelis* spp (0to1), *Orovenator mayorum* (0to1), *Mesenosaurus romeri* (0to1). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: Ophiacodontidae (0to1)

17. Premaxilla, supranarial (dorsal) process, suture with naris: single pronged or transversely flat (0); two-pronged (alary process present) (1)

Modesto *et al. (*2007 c.2), Modesto *et al. (*2014 c.2).

State 1 has been considered to be a synapomorphy of early and derived captorhinids (Müller and Reisz 2005, Modesto *et al. 2*007). This state is also independently present in *Varanosaurus* (Berman *et al.*1995).

Unambiguous: *Varanosaurus acutirostris* (0to1). DELTRAN: Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Euconcordia cunninghami* (0to1). ACCTRAN: *Thuringothyris mahlendorffae* (1to0), Captorhinidae (0to1)

18. Premaxilla, anteroventral slope of alveolar margin relative to ventral margin of maxilla: absent (0); slight, less than 10° from horizontal (1); moderate, 10-20° from horizontal (2); strong, 30-45° from horizontal (3);very strong > 45° from horizontal (4)

Modified from Carroll and Currie (1991 c.16), Reisz *et al.* (1992 c.3), Berman *et al. (*1995 c.3), Dodick and Modesto (1995 c.1), Dilkes (1998 c.6), Reisz *et al. (*2010 c.10), Fröbisch et *al. (*2011 c.96), Ezcurra *et al. (*2014 c.10), Benson (2012 c.13).

State (1) of this character is present in some caseasaurs (e.g. *Eothyris,* MCZ 1161, Reisz *et al. 2*009 and *Euromycter*, Reisz *et al. 2*010 Appendix S1 c.10) and diadectomorphs (Romer 1946, Moss 1972), as well as *Orovenator* and some parareptiles (e.g. *Acleistorhinus*, deBraga and Reisz 1996, Ford and Benson 2018). It is also present in sphenacodontians. Derived captorhinids possess a more pronounced inclination (state 2), with some examples of more extreme inclination (state 3), e.g. up to 45° in *Labidosaurus hamatus* and 35° in *Captorhinus aguti* (Modesto *et al. 2*007). The extreme state of anteroventral inclination (state 4) is present only in *Proterosuchus* in the context of the present study, and as such is phylogenetically uninformative, but is included for information only.

Unambiguous: *Proterosuchus* spp (1to4), *Acleistorhinus pteroticus* (0to1), *Milleretta rubidgei* (0to1), *Captorhinus aguti* (2to3), *Labidosaurus hamatus* (2to3), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to2), Diadectomorpha (0to1), *Euromycter rutena* (0to1), Sphenacodontia (0to1), *Orovenator mayorum* (0to1). DELTRAN: *Prolacerta broomi* (0to1), *Eothyris parkeyi* (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Eothyrididae (0to1)

19. Premaxilla, narial shelf: more or less sharp edge between lateral (= sculptured, if sculpture is present) surface of skull and ventral wall of naris (0); rounded ventral narial shelf that transitions smoothly into ventral edge of skull (1); inapplicable, premaxilla does not participate in narial shelf (-)

Modified from Reisz *et al. (*1998 c.2), Reisz and Dilkes (2003 c.2), Anderson and Reisz (2004 c.2), Reisz and Laurin (2004 c.2), Reisz *et al. (*2009 c.5), Maddin *et al. (*2006 c.7), Campione and Reisz (2010 c.7), Ezcurra *et al. (*2014 c.11), Benson (2012 c.15), Spindler *et al. (*2018 c.14).

Character state 1 has been considered by previous studies as a synapomorphy of all varanopids (i.e. early varanopids and derived mycterosaurines plus varanodontines, Reisz *et al.*1998, Reisz and Berman 2001, Reisz and Dilkes 2003, Anderson and Reisz 2004), and is also present in *Orovenator* (Ford and Benson 2018). However, Benson (2012) noted that a rounded narial shelf was present in the ophiacodontid *Varanosaurus*, and absent in the mycterosaurine *Heleosaurus* and in the varanodontines *Varanops* and *Varanodon*. Having examined the varanodontine specimens for the present study, we conclude that state (1) is indeed absent in *Varanops* (MCZ 1926), but that the condition in *Varanodon* is uncertain. We further consider the condition in *Heleosaurus* to be unknown, in accordance with the scoring of Botha-Brink and Modesto (2009).

Unambiguous: *Varanosaurus acutirostris* (0to1).DELTRAN: Varanopidae except *Ascendonanus* (0to1), *Varanops brevirostris* (1to0). ACCTRAN: Varanopidae (0to1), Varanodontinae except *Aerosaurus wellesi* (1to0)

20. Premaxilla, tooth size compared to marginal maxillary teeth: small or subequal to (non-caniniform) maxillary teeth (0); premaxillary teeth larger (1)

Modified from Gauthier *et al. (*1988 c.114), Reisz *et al. (*1992 c.60), Laurin (1993 c.6), Modesto (1994 c.2), Modesto *et al. (*2007 c.34), Reisz *et al. (*2011 c.36), Benson (2012 c.18).

Diadectomorphs (Moss 1972, Berman *et al. 2*010), eothyridids (Reisz *et al. 2*009) and captorhinids (Modesto *et al. 2*007, Fox and Bowman 1966) all possess premaxillary teeth that are substantially larger than the non-caniniform maxillary teeth. This state is also shared by sphenacodontians (Romer and Price 1940, Reisz *et al.*1992; including many therapsids), ophiacodontids (Berman *et al.*1995, Romer and Price 1940), *Hylonomus* (Carroll 1969), *Petrolacosaurus* (Reisz 1981) and *Colobomycter* (MacDougall *et al. 2*017).

Unambiguous: *Deltavjatia rossicus* (0to1), *Colobomycter pholeter* (0to1), *Stereosternum tumidum* (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Ennatosaurus tecton* (0to1), *Hylonomus lyelli* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Diadectomorpha (0to1), Eothyrididae (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontidae (0to1), *Haptodus garnettensis* (0to1). ACCTRAN: Reptilia (1to0), Amniota + Diadectomorpha (0to1), Caseidae (1to0), *Pantelosaurus saxonicus* (1to0), Edaphosauridae (1to0)

21. Premaxilla, tooth size: isodont (0); anterior teeth larger than posterior teeth (1)

Modified from Laurin (1993 c.67), Fröbisch et *al. (*2011 c.53).

Variation in the size of premaxillary teeth might be considered as non-independent from the preceding character. However, several taxa possess the derived state of ch.20 above, but nevertheless have an isodont array of premaxillary dentition (e.g. *Tseajaia*, Moss 1972 and *Euconcordia*, Müller and Reisz 2005), whereas others possess large anterior premaxillary teeth that are subequal to the non-caniniforms (e.g. varanodontines, FMNH UC 986, Campione and Reisz 2010; *Protorothyris*, Clark and Carroll 1973 and *Macroleter*, Tsuji *et al. 2*006). Therefore, ch.20 and ch.21 vary independently of each other and are both included in the analysis.

Unambiguous: Varanodontinae (0to1), *Macroleter poezicus* (0to1), *Colobomycter pholeter* (0to1), Captorhinidae except *Euconcordia* (0to1), *Limnoscelis paludis* (0to1), *Ennatosaurus tecton* (0to1), *Protorothyris archeri* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Eothyrididae (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontia (0to1). ACCTRAN: Synapsida (0to1), Caseidae (1to0), Edaphosauridae (1to0)

22. Septomaxilla, morphology in lateral view: a thin superficial bone that forms the ventral margin of the external naris (0); a rectangular sheet of bone shaped as a conical funnel (1); an anteroposteriorly broad sheet of bone, which lies medial to the superficial surface of the circumnarial bones, and fully or partially partitions the external naris (2); a pillar of bone, partitioning the naris or forming the posterior margin of the external naris, with superficial exposure (3)

Modified from Modesto (1994 c.8), Reisz and Dilkes (2003 c.42), Maddin *et al. (*2006 c.8), Reisz *et al. (*2009 c.10/11), Reisz *et al. (*2010 c.18/19), Benson (2012 c.19).

Character states for the septomaxillae used in early studies focused almost exclusively in the absence or presence of a superficial contact with the circumnarial elements (Gauthier *et al.*1988 c.3, Reisz 1992 c.6, Laurin 1993 c.4, deBraga and Rieppel 1997 c.5, Berman *et al.*1995 c.7). This distinction is maintained here (state 3), and is present in sphenacodontians (Romer and Price 1940, Laurin 1993), edaphosaurs (Modesto 1995), varanodontines (Campione and Reisz 2010) and *Procolophon* (Carroll and Lindsey 1985). The ’conical funnel’ morphology (state 1) is a synapomorphy of the captorhinids included in the present taxon list, where this element is preserved (Fox and Bowman 1966, *Captorhinus aguti* OMNH 15101, *Protocaptorhinus pricei* MCZ 1478, *Romeria primus* MCZ 1963, Sumida *et al. 2*010).

In *Limnoscelis* (Berman *et al.* 2010), caseids (Olson 1968, Sigogneau-Russell and Russell 1974), *Archaeovenator* (Reisz and Dilkes 2003), *Orovenator* (Reisz *et al.* 2011), *Araeoscelis* (MCZ 4380), archosauromorphs (Modesto and Sues 2004, Ezcurra and Butler 2015) and most parareptiles (MacDougall *et al.* 2017, Daly 1969), there is no superficial exposure of the septomaxilla, which forms a sheet-like element within the naris (state 2). *Seymouria* and the early parareptile *Mesosaurus* possess a dorsoventrally narrow septomaxilla that is situated on the ventral surface of the external naris (state 0).

Unambiguous: Mesosauridae (2to0), *Labidosaurus hamatus* (1to2), Amniota + Diadectomorpha (0to2), Ophiacodontidae + Sphenacodontia + Edaphosauridae (2to3). DELTRAN: *Procolophon trigoniceps* (2to3), Captorhinidae except *Euconcordia* and *Thuringothyris* (2to1), *Varanops brevirostris* (2to3). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (2to3), Ankyramorpha except Lanthanosuchoidea (2to3), Captorhinidae (2to1)

23. Maxilla, preorbital ascending process: convex dorsal margin that does not divide lacrimal (0); divides lacrimal in lateral view (1)

Modified from Reisz (1992 c.29), Berman et al. (1995 c.34), Reisz et al. (1998 c.5), Maddin *et al. (*2006 c.9), Benson (2012 c.25).

This character describes the acumate dorsal process of the maxilla that overlaps the surface of the lacrimal, dividing it into a pre- and post-maxillary dorsal process regions. This is present in *Varanodon* and *Varanops* (FMNH UC 986, MCZ 1926), and independently in the parareptiles *Colobomycter pholeter* (MacDougall *et al.* 2017) and *Delorhynchus* (Reisz *et al.* 2014).

Unambiguous: *Colobomycter pholeter* (0to1), *Varanops* + *Varanodon* + *Watongia* (0to1).

24. Maxilla, preorbital ascending process, maximum dorsoventral height in respect to the height of the maxilla at the anterior orbital margin: less than 1.5 times the height (0); between 1.5 and twice the height (1); greater than twice the height (2)

Modified from Laurin (1993 c.29), Berman *et al. (*1995 c.34), Reisz and Dilkes (2003 c.5), Benson (2012 c.25), Spindler *et al. (*2018 c.21).

The dorsoventral extension of the preorbital ascending process of the maxilla is a distinctive morphology of many early amniotes. Previous studies only describe this quantitatively, as either ’tall’ or ’short’, or described the position of the apex of the process relative to the external naris e.g. Laurin and Reisz (1995 c.19), Reisz *et al. (*2007 c.19). The lowest ratio, state (0), describes the process found in diadectomorphs, caseasaurs, ’protorothyridids’, araeoscelidians and most captorhinids. This distribution suggests that state (0) represents the plesiomorphic condition. Derived ophiacodontids, sphenacodontids, varanodontines, some mycterosaurines and neodiapsids possess the highest ratio state (2).

Unambiguous: Neodiapsida except *Claudiosaurus* (1to2), *Deltavjatia rossicus* (1to2), Owenettidae (1to2), *Stereosternum tumidum* (1to2), Varanopidae + Neoreptilia (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to1), *Seymouria* spp (0to1), *Ophiacodon* spp (1to2), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). DELTRAN: Mycterosaurinae (1to2), *Belebey vegrandis* (1to0), *Procolophon trigoniceps* (1to0), *Milleretta rubidgei* (1to0), Sphenacodontidae (1to2), Varanodontinae except *Aerosaurus wellesi* (1to2). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to2), Procolophonoidea (1to0), Ankyramorpha (0to1), Parareptilia except Mesosauridae (1to0), Sphenacodontidae + *Cutleria wilmarthi* (1to2), *Aerosaurus wellesi* (2to1)

25. Maxilla, position of apex of preorbital ascending process: process absent or very low (0); tallest point located centrally between the orbit and external naris (1); tallest point located anteriorly, immediately posterior to the external naris (2); tallest point located anterior to the external naris (3)

From Laurin and Reisz (1995 c.19), Reisz *et al. (*2007 c.19), Maddin *et al. (*2008 c.9).

In *Stereosternum tumidum* and *Mesosaurus tenuidens* the tallest point of the maxilla is anterior to the external naris (Modesto 1999, Modesto 2006).

Unambiguous: *Prolacerta broomi* (1to2), *Claudiosaurus germaini* (1to2), *Procolophon trigoniceps* (2to1), Mesosauridae (1to3), Amniota (0to1), *Seymouria* spp (0to2), *Euromycter rutena* + *Ennatosaurus tecton* (1to2). DELTRAN: *Acleistorhinus pteroticus* (1to2), Ankyramorpha except Lanthanosuchoidea (1to2). ACCTRAN: *Colobomycter pholeter* (2to1), Ankyramorpha (1to2)

26. Maxilla, contact with prefrontal: absent, separated by the anterior extension of the lacrimal (0); present, lacrimal is reduced anteriorly allowing contact (1)

Modified from Gauthier *et al. (*1988 c.27), Laurin (1993, c.27), Reisz *et al. (*1998 c.6), Maddin *et al. (*2006 c.10), Reisz *et al. (*2009 c.24), Fröbisch et *al. (*2011 c.10), Benson (2012 c.53), Spindler *et al. (*2018 c.20).

Character state 1 is present in mycterosaurines, some neodiapsids and lanthanosuchoid parareptiles. Spindler *et al. (*2018) noted that in their analysis this character is redundant with the character defining the contribution of the lacrimal to the external nares (ch. 50 present study). However, in sphenacodontids (Romer and Price 1940, Reisz *et al.*1992), neodiapsids (Carroll 1981, Modesto and Reisz 2003), archosauromorphs (Modesto and Sues 2004, Ezcurra and Butler 2015) and some parareptiles (Tsuji 2006, Carroll and Lindsey 1985) the lacrimal prevents contact between the maxilla and the prefrontal (state 0) and does not contribute to the external naris or the septomaxilla. Consequently both characters are maintained here.

Unambiguous: Mycterosaurinae (0to1), *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), Lanthanosuchoidea (0to1)

27. Maxilla, parallel row of lateral (supralabial) maxillary foramina: absent (0); present (1)

Modified from Laurin and Reisz (1995 c.20 state 2).

Many early amniotes have a distinctive row of supralabial foramina (state 1) located ventrally on the lateral surface of the maxilla (e.g. early varanopids and varanodontines, Reisz and Dilkes 2003, Anderson and Reisz 2004, Langston and Reisz 1981, Campione and Reisz 2010; *Orovenator*, Reisz *et al. 2*011; *Petrolacosaurus*, Reisz 1981; *Lanthanolania*, Modesto and Reisz 2003 and archosauromorphs, Modesto and Sues 2004). The caseid *Ennatosaurus* also has a row of large maxillary foramina extending dorsally along the lateral surface of the maxilla (Maddin *et al. 2*008), with a similar arrangement ventrally on the lateral surface in *Euromycter* (Sigogneau-Russell and Russell 1974). Ophiacodontids, sphenacodontians and edaphosaurids do not possess a distinctive row of maxillary foramina.

Unambiguous: *Lanthanolania* + Archosauromorpha (0to1), Pareiasauria + Nycteroleteridae (0to1), *Euromycter rutena* + *Ennatosaurus tecton* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1). ACCTRAN: Varanopidae (0to1)

28. Maxilla, anterior lateral (supralabial) maxillary foramen: equal in size to other maxillary foramina, if present (0); much larger than other foramina or a single large foramen (1); inapplicable, maxillary foramina absent (-)

Modified from Laurin and Reisz (1995 c.20), Dilkes (1998 c.17), Modesto and Sues (2004 c.17), Tsuji (2006 c.21), Maddin *et al. (*2008 c.3), Benson (2012 c.24), Modesto *et al. (*2015 c.30).

The anterior-most maxillary foramen is distinctly larger than the other maxillary foramina in some taxa, and gives rise to an anteriorly directed groove. This condition is found in *Orovenator* (Ford and Benson 2018), some early varanopids and mycterosaurines (Reisz and Dilkes 2003, Botha-Brink and Modesto 2009) and archosauromorphs (Modesto and Sues 2004). In parareptiles, a row of supralabial foramina is often absent. Instead a single large foramen is present, which is a synapomorphy of parareptiles (Tsuji 2006).

Unambiguous: *Heleosaurus scholtzi* (0to1). DELTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), Archosauromorpha (0to1), Parareptilia except Mesosauridae (0to1). ACCTRAN: Varanopidae except *Ascendonanus, Orovenator* and *Archaeovenator* (1to0), *Lanthanolania ivakhnenkoi* (1to0), Varanopidae + Neoreptilia (0to1)

29. Maxilla, multiple tooth rows: absent, single row of marginal teeth only (0); present, at least two rows of marginal teeth (1)

From Dodick and Modesto (1995 c.36), Modesto *et al.* (2007 .35)

Unambiguous: *Captorhinus aguti* (0to1), *Labidosaurikos meachami* (0to1)

30. Maxilla, marginal tooth number (count): 10 or fewer (0); 13-27 (1); 28-34 (2); 35 or more (3); inapplicable, multiple tooth rows are present (-)

Modified from Carroll and Currie (1991 c.29), Laurin (1993 c.73), Berman *et al. (*1995 c.65), Reisz *et al. (*1998 c.28), Maddin *et al. (*2006 c.2), Maddin *et al. (*2008 c.64), Reisz *et al. (*2009 c.20), Benson (2012 c.29), Spindler *et al. (*2018 c.27).

Many studies omit characters defining the total maxillary tooth count (Gauthier *et al.* 1988, Reisz 1992, Laurin and Reisz 1995, Modesto 1995, deBraga and Reisz 1996, Fröbisch et *al. 2*011 - post- caniniform teeth only). Analysis of the tooth count in the current taxon list exhibits clustering from which we derive the defined states. Several groups (e.g. derived mycterosaurines, varanodontines, captorhinids, most parareptiles and caseasaurs) are scored as state (1). The out-group taxon, *Gephyrostegus*, possessed at least 35 maxillary teeth (Klembara *et al. 2*014), which is also the condition in derived ophiacodontids, *Ianthasaurus hardestiorum*, some 'protorothyridids' and some neodiapsids. Early varanopids (e.g. *Archaeovenator, Pyozia*, and *Orovenator*) and *Youngina* are scored as state (2). The reduction of maxillary teeth to 10 or less is shared by derived herbivores (e.g. *Ennatosaurus*, Maddin *et al. 2*008; *Procolophon*, Cisneros 2008 and *Belebey*, Reisz *et al. 2*007).

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (1to2), *Youngina capensis* (3to2), *Emeroleter levis (*1to2), *Procolophon trigoniceps* (1to0), *Nyctiphruretus acudens* (1to2), 'protorothyridids' (1to3), *Ennatosaurus tecton* (1to0), *Varanosaurus acutirostris* + *Ophiacodon* spp (2to3), *Ianthasaurus hardestiorum* (1to3), *Protorothyris archeri* (3to2), *Petrolacosaurus kansensis* (1to3).

DELTRAN: *Acerosodontosaurus piveteaui* (1to3), *Claudiosaurus germaini* (1to3), *Belebey vegrandis* (1to0), *Deltavjatia rossicus* (1to0), *Gephyrostegus bohemicus* (1to3), *Archaeothyris florensis* (1to2). ACCTRAN: *Lanthanolania* + Archosauromorpha (3to1), *Eudibamus cursoris* + *Belebey vegrandis* (1to0), *Emeroleter levis* + *Deltavjatia rossicus* (1to0), Neodiapsida (1to3), *Gephyrostegus bohemicus* (1to3), Ophiacodontidae except *Echinerpeton* (1to2)

31. Maxilla, caniniform teeth: absent (0); present (1)

Dodick and Modesto (1995 c.35), Laurin and Reisz (1995 c.24/25), Modesto (1994 c.4), Dilkes (1998 c.56), Reisz and Dilkes (2003 c.39), Maddin *et al. (*2006 c.4), Maddin *et al. (*2008 c.69), Benson (2012 c34), Spindler *et al. (*2018 c.30).

For clarity, we define caniniform teeth as anterior maxillary teeth distinctively larger than all other maxillary teeth. They are found in many early amniotes and their close relatives. Where more than two caniniform teeth are present we define this as a caniniform region. Caniniform maxillary teeth, as a region or as one or two teeth, are present in *Seymouria* (Berman *et al. 2*000) and diadectomorphs (Moss 1972, Berman *et al. 2*010), eothyridids (Reisz *et al. 2*009), ophiacodontids and sphenacodontians (Romer and Price 1940), captorhinids (Sumida *et al. 2*010), varanodontines, (Maddin *et al. 2*006), derived mycterosaurines (Berman and Reisz 1982), 'protorothyridids' (Carroll 1969), araeoscelidian diapsids (Reisz 1981) and some parareptiles (e.g. *Macroleter poezicus*, Tsuji 2006). Caniniforms are absent in neodiapsids (Gow 1975, Modesto and Sues 2004), some parareptiles (Modesto *et al. 2*015), early varanopids (e.g. *Archaeovenator*, Reisz and Dilkes 2003) and derived herbivores (parallel adaptation in caseids and edaphosaurs as suggested by Reisz 1980).

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (1to0), *Macroleter poezicus* (0to1), Owenettidae (0to1), *Colobomycter pholeter* (0to1), Neoreptilia (1to0), *Labidosaurikos meachami* + *Labidosaurus hamatus* (1to0), *Thuringothyris mahlendorffae* (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), Caseidae (1to0), *Edaphosaurus boanerges* (1to0)

32. Maxilla, caniniform teeth number (count): more than two caniniform teeth present (caniniform region) (0); one or two caniniform teeth present (1); inapplicable, caniniform teeth absent (-)

Modified from Modesto (1994 c.3), Benson (2012 c.34), Spindler *et al. (*2018 c.32).

Unambiguous: Ankyramorpha except Lanthanosuchoidea (1to0), *Euconcordia cunninghami* (1to0), *Limnoscelis paludis* (1to0), *Ophiacodon* spp (1to0), *Pantelosaurus saxonicus* (1to0), *Aerosaurus wellesi* (1to0), *Mycterosaurus longiceps* (1to0)

33. Maxilla, caniniform teeth, size: slightly larger than the adjacent maxillary teeth (0); at least 1.5 times as large as adjacent maxillary teeth (1); inapplicable, caniniform teeth absent (-)

Modified from Reisz *et al. (*1992 c.59), Reisz *et al. (*2009 c.17), Benson (2012 c.34), Spindler *et al. (*2018 c.31).

Unambiguous: *Ophiacodon* spp (1to0). DELTRAN: *Colobomycter pholeter* (0to1), Araeoscelidia (0to1), *Romeria* spp (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to1), Synapsida (0to1), *Tseajaia campi* (0to1), *Paleothyris acadiana* + *Protorothyris archeri* (0to1). ACCTRAN: Lanthanosuchoidea (0to1), Varanopidae + Neoreptilia (1to0), *Reiszorhinus olsoni* (1to0), *Euconcordia cunninghami* (1to0), Amniota + Diadectomorpha (0to1), *Limnoscelis paludis* (1to0), *Hylonomus lyelli* (1to0)

34. Maxilla, secondary caniniform region: absent (0); present (1); inapplicable, caniniform teeth absent (-)

Maddin *et al. (*2008 c.66), Reisz *et al. (*2009 c.18), Benson (2012 c.39), Spindler *et al. (*2018 c.33).

The eothyridids *Eothyris* and *Oedaleops* possess a secondary series of caniniform teeth posterior to the two large caniniforms (Langston 1965, Reisz *et al. 2*009).

DELTRAN: Eothyrididae (0to1). ACCTRAN: Caseasauria (0to1).

35. Maxilla, number of pre-caniniform maxillary teeth: five or less (0); six or more (1); inapplicable, caniniform teeth absent (-)

Modified from Reisz *et al. (*1992 c.62), Laurin (1993 c.71), Berman *et al. (*1995 c.69), Maddin *et al. (*2008 c.65), Reisz *et al. (*2009, c.16), Fröbisch et *al. (*2011 c.57), Benson (2012 c.32), Spindler *et al. (*2018 c.29).

Unambiguous: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), *Secodontosaurus obtusidens* (0to1), *Haptodus garnettensis* (0to1), *Petrolacosaurus kansensis* (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1). DELTRAN: *Paleothyris acadiana* + *Protorothyris archeri* (0to1). ACCTRAN: 'protorothyridids' except *Hylonomus* (0to1)

36. Maxilla, lateral 'supracanine' buttress: absent or slight swelling (0), distinct lateral swelling or dorsally oriented ridge on the maxilla, dorsal to the caniniform dentition (1)

Reisz *et al. (*1998 c.10), Reisz and Dilkes (2003 c.10), Maddin *et al. (*2006 c.11), Reisz *et al.* (2009 c.13), Benson (2010 c.36), Brocklehurst *et al. (*2016 c.25), Spindler *et al. (*2018 c.24).

Several early amniotes possess a lateral extension of the maxilla immediately dorsal to the caniniform dentition. This is often present as a swelling on the lateral surface of the maxilla (e.g. *Eothyris,* Reisz *et al. 2*009; *Varanosaurus*, Berman *et al.*1995 and *Dimetrodon* milleri, MCZ 1365), or forms a dorsoventral ridge that overlies the lacrimal (e.g. *Varanops* and *Varanodon*, Campione and Reisz 2010, FMNH UC 986). In the mycterosaurines *Heleosaurus* (Botha-Brink and Modesto 2009) and *Mesenosaurus* (Reisz and Berman 2001) only a slight lateral swelling of the maxilla is present, which is not sufficiently well developed to be considered as state (1), in accordance with Spindler *et al. (*2018). Langston and Reisz (1981) noted a 'suggestion of a lateral ridge' in *Aerosaurus wellesi*, somewhat similar to that of *Varanops* and *Varanodon*, which we also consider as insufficient evidence to score as the derived state, in agreement with the coding of Benson (2012) and Spindler *et al. (*2018).

Unambiguous: *Varanosaurus acutirostris* (0to1), *Dimetrodon* spp (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1). DELTRAN: *Eothyris parkeyi* (0to1). ACCTRAN: *Eothyris parkeyi* + *Eocasea martini* + *Vaughnictis smithae* (0to1)

37. Maxilla, 'supracanine' buttress on medial surface: absent, alveolar shelf has uniform or gradually tapering dorsoventral height (0); present, subtriangular dorsal thickening of anterior alveolar shelf (1)

Modified from Reisz *et al. (*1992 c.27), Laurin (1993 c.28/70), Berman *et al. (*1995 c.33), Fröbisch et *al. (*2011 c.21/56), Benson (2012 c.37), Spindler *et al. (*2018 c.25).

In some early amniotes, where caniniform teeth are present, a thickening and dorsal expansion of the alveolar ridge onto the medial surface of the maxillary lamina is also present, which contains the roots of the larger teeth (Reisz 1986). Although, this medial buttress is absent in the caseasaur *Oedaleops*, which possesses large caniniform teeth (Langston 1965). Conversely, in *Archaeovenator*, *Orovenator* and *Prolacerta*, where caniniform teeth are absent, a medial buttress of the maxilla is present (KUVP 12483, Modesto and Sues 2004, Ford and Benson 2018).

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1). DELTRAN: *Prolacerta broomi* (0to1), Sphenacodontia (0to1), Ophiacodontidae (0to1). ACCTRAN: Neodiapsida (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

38. Maxilla, morphology of dorsal portion of 'supracanine' buttress: anteroposteriorly broad region of thickened bone (0); narrow, strut-like ascending process extends posterodorsally from supracanine buttress (1); inapplicable, supracanine buttress absent (-)

Modified from Reisz *et al. (*1992 c.27), Laurin (1993 c.28), Fröbisch et *al. (*2011 c.21), Benson (2012 c.38).

A narrow, posterodorsal extension of the 'supracanine' buttress (state 1) is present in derived ophiacodontids (Romer and Price 1940, Berman *et al.*1995), in *Orovenator* (Ford and Benson 2018) and in *Prolacerta* (Gow 1975).

Unambiguous: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). DELTRAN: Varanopidae + Neoreptilia (0to1). ACCTRAN: Reptilia (0to1)

39. Maxilla, orientation of lateral antorbital surface: vertical or slopes weakly dorsomedially (0); slopes dorsolaterally, overhanging tooth row (1)

Modified from Maddin *et al. (*2008 c.2), Reisz *et al. (*2009 c.14), Benson (2012 c.21), Romano *et al. (*2015 c.324), Brocklehurst *et al. (*2016 c.21), Spindler *et al. (*2018 c.26).

The derived state (state 1) of this character is present in caseasaurs (Reisz *et al. 2*009, Maddin *et al. 2*008). Most of the previous studies using this character have also scored for state (1) in diadectomorphs, with only Reisz *et al. (*2009) scoring for state (0) in this clade. We have not been able to examine any specimens that support presence of either state in diadectomorphs. Neither do we find any confirmation of this feature in the available literature. Consequently we score *Tseajaia* and *Limnoscelis* as unknown. Several studies (Benson 2012, Romano *et al. 2*015, Brocklehurst *et al. 2*016, Spindler *et al. 2*018) scored *Captorhinus* as possessing state (1). Recent phylogenetic studies concerned with the interrelationships of captorhinids omit this character altogether (e.g. Modesto *et al. 2*018, Reisz *et al. 2*015, Modesto *et al. 2*014, Modesto *et al. 2*007, Sumida *et al. 2*010, Müller and Reisz 2005). Heaton (1979) noted that the lateral surface of the maxilla is vertical in both *Captorhinus laticeps* and *C. aguti.* Personal examination of several specimens (*C. aguti* FMNH UC 242, MCZ 1768, OMNH 56819; *C. laticeps* FMNH UC 701, OMNH 15101) and other literature sources (Fox and Bowman 1966, Modesto 1998) do not support the presence of state (1) in *Captorhinus*. Likewise, specimens of *Protocaptorhinus pricei* (MCZ 1478), *Romeria primus* (MCZ 1963) and *Romeria texana* (MCZ 1480) show no evidence of a dorsolaterally orientated maxillary lamina. However the holotype specimen of *Reiszorhinus olsoni* (FMNH UC 183) does possess a distinctive dorsolateral inclination of the maxilla, and is scored as state (1) herein.

Unambiguous: Caseasauria (0to1), *Reiszorhinus olsoni* (0to1).

40. Maxilla, orientation of lateral surface of suborbital ramus: vertical, with no lateral overhang of tooth row (0); dorsolaterally inclined, overhangs tooth row (1)

NEW

Archaeovenator, *Orovenator* and *Labidosaurikos* share a feature of the suborbital ramus of the maxilla where a distinct dorsolateral inclination causes the dorsal edge of the maxilla to overhang the marginal tooth row (state 1)(Reisz and Dilkes 2003, Ford and Benson 2018, Dodick and Modesto 1995). This state is also present in taxa where dorsolateral inclination of the antorbital lateral surface of the maxilla continues on the surface of the suborbital ramus, e.g. caseasaurs and *Reiszorhinus olsoni* (see ch.39 above).

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Labidosaurikos meachami* (0to1), *Reiszorhinus olsoni* (0to1), Caseasauria (0to1)

41. Maxilla, shape: relatively straight or mildly convex (0); posterior end flexed laterally resulting in concave outline seen in dorsal/ventral view (1)

Modified from Dodick and Modesto (1995 c.2), Müller *et al. (*2006 c.2), Modesto *et al. (*2007 c.3), Modesto *et al. (*2018 c.4).

The lateral flexure of the maxilla is a synapomorphy of derived captorhinids (Müller et *al. 2*006, Modesto *et al. 2*018), which is also present in diadectomorphs (Heaton and Reisz 1986, Berman *et al. 2*010). A similar condition is found independently in the early synapsid *Edaphosaurus* (Modesto 1995) and the parareptile *Procolophon* (Carroll and Lindsey 1985) suggesting that this feature may be a parallel adaptation for derived herbivory.

Unambiguous: *Procolophon trigoniceps* (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), Diadectomorpha (0to1), *Edaphosaurus boanerges* (0to1)

42. Maxilla, posterior extension: maxilla terminates posteriorly at the level of or posterior to the posterior orbital rim (0); anterior to the posterior orbital rim (1)

Modified from Modesto (1994 c.7), deBraga and Rieppel (1997 c.14), Müller (2004 c.127), Ezcurra *et al. (*2014 c.122).

Unambiguous: Mycterosaurinae + Varanodontinae (1to0), *Emeroleter levis (*1to0), Lanthanosuchoidea (1to0), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (0to1), Captorhinidae except *Euconcordia* (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Heleosaurus scholtzi* + *Mesenosaurus romeri* (0to1).DELTRAN: *Proterosuchus* spp (1to0), *Lanthanolania ivakhnenkoi* (1to0), *Eothyris parkeyi* + *Eocasea martini* + *Vaughnictis smithae* (1to0), Caseidae (1to0), *Paleothyris acadiana* + *Protorothyris archeri* (1to0). ACCTRAN: *Prolacerta broomi* (0to1), *Lanthanolania* + Archosauromorpha (1to0), *Oedaleops campi* (0to1), Caseasauria (1to0), 'protorothyridids' except *Hylonomus* (1to0)

43. Maxilla, posterior extent of dentition if posterior extension level with or posterior to posterior orbital rim: anterior to the posterior orbital rim exclusively (0); terminates ventral to the posterior orbital rim (1); continues posterior to the posterior orbital rim (2) inapplicable, maxilla terminates anterior to the posterior orbital rim (-)

Modified from Rieppel (1999 c.57), Müller (2004 c.118), Maddin *et al. (*2008 c.11), Reisz *et al. (*2009 c.15), Benson (2012 c.30), Reisz and Fröbisch (2014 c.11), Spindler *et al. (*2018 c.28).

The posterior extent of the maxilla (ch.42) and the posterior extent of the maxillary tooth row are partially independent characters that provide separate and phylogenetically informative data. The maxilla extends posterior to the posterior orbital rim in varanodontines, *Mycterosaurus* (Berman and Reisz 1982) and *Elliotsmithia* (Reisz *et al.*1998). In previous studies (Maddin *et al. 2*008, Reisz and Fröbisch 2014, Benson 2012, Spindler *et al. 2*018) *Mycterosaurus* is scored as possessing a tooth row that extends beyond the posterior orbital rim. However, a microCT scan of the holotype of this taxon (FMNH UC 692, Berman and Reisz 1982) has revealed the tooth row terminates anterior to the posterior orbital rim, a condition shared with *Elliotsmithia*. Consequently, in the present study the tooth row is scored as extending posterior to the posterior orbital rim in varanodontines (state 2), and as terminating anteriorly in *Mycterosaurus* and *Elliotsmithia* (state 0).

Unambiguous: Varanodontinae (0to2), *Acleistorhinus pteroticus* (0to1), *Romeria* spp + *Reiszorhinus olsoni* (1to0). DELTRAN: *Proterosuchus* spp (0to1), *Emeroleter levis (*0to2), Varanopidae + Neoreptilia (1to0), *Gephyrostegus bohemicus* (1to2), *Protorothyris archeri* (1to0). ACCTRAN: Archosauromorpha (0to1), Ankyramorpha except Lanthanosuchoidea (0to2), Reptilia except Captorhinidae (1to0), *Gephyrostegus bohemicus* (1to2), *Paleothyris acadiana* (0to1)

44. Maxilla, ventral surface in lateral view: straight or weakly convex (0); pronounced convexity (1)

Modified from Gauthier *et al. (*1988 c.30), Reisz *et al. (*1992 c.25), Berman *et al. (*1995 c.31), Reisz and Dilkes (2003 c.52), Maddin *et al. (*2008 c.12), Benson (2012 c.27 with state (2) omitted as uninformative).

In the current taxon list, state (1) is present in diadectomorphs, derived ophiacodontids and sphenacodontians. Benson (2012) included a third state to account for the 'pre-canine' step in *Dimetrodon* and more derived sphenacodontids/therapsids. This state is omitted here as parsimony uninformative (the step is only present in *Dimetrodon* among the taxa in the analysis). The mild convexity in the anterior part of the ventral margin of the maxilla in *Ennatosaurus* is scored as state (0) herein contra Maddin *et al. 2*008.

Unambiguous: Diadectomorpha (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), *Cutleria wilmarthi* (1to0), Sphenacodontia (0to1)

45. External naris, posterodorsal expansion: absent (0); present (1)

Modified from Reisz and Dilkes (2003 c.43), Maddin *et al. (*2006 c.42), Reisz *et al. (*2009 c.9), Reisz *et al. (*2010 c.21), Benson (2012 c.4 in part), Spindler *et al. (*2018 c.5).

Reisz and Dilkes (2003 c.43) introduced a multistate character describing the presence, absence, size and composition of the narial posterodorsal expansion in early varanopids, mycterosaurines and varanodontines. We instead score a pair of hierarchically related characters (the present character and ch.46 below) in which the presence/absence and composition are coded as binary characters. The posterodorsal expansion of the naris is present in early varanopids, mycterosaurines and varanodontines (Reisz and Dilkes 2003, Reisz *et al. 2*010, Campione and Reisz 2010), with the exception of *Aerosaurus* (Langston and Reisz 1981). It is also present in *Orovenator* (Ford and Benson 2018).

Unambiguous: *Aerosaurus wellesi* (1to0). DELTRAN: Varanopidae except *Ascendonanus* (0to1). ACCTRAN: Varanopidae (0to1)

46. External naris, morphology of posterodorsal expansion if present: pinched between nasal and maxilla (0); greatly enlarged, between nasal and lacrimal (1); inapplicable, posterodorsal expansion absent (-)

Modified from Reisz and Dilkes (2003 c.43), Maddin *et al. (*2006 c.42), Reisz *et al. (*2009 c.9), Reisz *et al. (*2010 c.21), Benson (2012 c.4 in part), Spindler *et al. (*2018 c.5).

In *Orovenator* and some early varanopids and mycterosaurines the posterodorsal expansion of the naris is narrow, and is pinched between the nasal and the maxilla (state 0) (Berman and Reisz 1982, Reisz and Dilkes 2003, Ford and Benson 2018). In *Archaeovenator* and varanodontines the posterodorsal expansion is significantly larger, with the lacrimal forming the ventral margin (state 1) (Reisz and Dilkes 2003, Maddin *et al. 2*006).

Unambiguous: *Archaeovenator hamiltonensis* (0to1). DELTRAN: Varanodontinae except *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1)

47. External naris, position: marginal (minimal distance between nares ≥0.35 snout width at same level) (0); close to midline (1)

Laurin (1991 F.2), deBraga and Rieppel (1991 c.6/7), Dilkes (1998 c.11), Reisz *et al.*

*(*2010 c.20).

Laurin (1991) included state (1) of this character as a synapomorphy of Archosauromorpha. We score it also as being present in the late Permian neo-diapsid *Claudiosaurus*. Reisz *et al. (*2010) scored the derived state present in *Varanodon*, but examination of FMNH UR 986 leads us to score this taxon as state (0) herein. In *Emeroleter levis* and *Deltavjatia rossicus* the dorsal process of the premaxilla is transversely very narrow and the nares face anteriorly in the latter taxon (Tsuji 2013).

Unambiguous: *Emeroleter levis + Deltavjatia rossicus* (0to1). DELTRAN: Archosauromorpha (0to1), *Claudiosaurus germaini* (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (1to0), Neodiapsida (0to1)

48. Nasal, length: distinctly shorter than the frontal (0); approximately equal to the frontal (1); longer than frontal (2)

Modified from Gauthier (1988 c.4), Reisz *et al. (*1992 c.7), Laurin (1993 c.5), Berman *et al. (*1995, c8/9), Reisz and Dilkes (2003 c.50), Müller (2004 c.4), Reisz *et al. (*2009 c.7), Maddin *et al. (*2006 c.14) Fröbisch et *al. (*2011 c.4), Benson (2012 c.47), Spindler *et al. (*2018 c.35).

Unambiguous: *Deltavjatia rossicus* (0to1), Mesosauridae (0to2). DELTRAN: Mycterosaurinae + Varanodontinae (0to1), *Youngina capensis* (0to1), Archosauromorpha (0to2), *Belebey vegrandis* (0to1), Diadectomorpha (0to1), *Seymouria* spp (0to1), *Euromycter rutena* (0to1), Casea broilii (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2), Sphenacodontidae + *Cutleria wilmarthi* (0to2). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), *Lanthanolania* + Archosauromorpha (1to2), Neodiapsida except *Claudiosaurus* (0to1), Bolosauria (0to1), Amniota (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Ennatosaurus tecton* (1to0), Caseidae (0to1), Sphenacodontia except *Haptodus* (0to2), Ophiacodontidae (0to2)

49. Nasal, external narial shelf: absent (0); present as a lateral fossa (1)

Modified from Reisz 1986 (table 3a), Laurin and Reisz (1995 c.1), Reisz and Dilkes (1998 c.49), Maddin *et al. (*2006 c.13), Reisz *et al. (*2007 c.1), Reisz *et al. (*2009 c.6), Benson (2012 c.48), MacDougall and Reisz (2014 c.1), Modesto *et al. (*2015 c.1), Spindler *et al. (*2018 c.36).

State (1) of this character has long been recognized as being present in all caseasaurs (Olson 1968, Reisz 1986, Reisz *et al. 2*009). Laurin and Reisz (1995) considered the lateral narial fossa as an independently derived autapomorphy of Procolphonidae. More recent studies have recognized the wider distribution of this feature amongst ankyramorph parareptiles (Modesto *et al. 2*015).

Unambiguous: *Colobomycter pholeter* (0to1), Caseasauria (0to1). DELTRAN: *Owenetta kitchingorum* (0to1), *Procolophon trigoniceps* (0to1). ACCTRAN: *Candelaria barbouri* (1to0), Procolophonoidea (0to1)

50. Lacrimal, length: participates in margin of external naris or contacts the posterior margin of the septomaxilla (0); does not reach external naris or septomaxilla (1)

Modified from Gauthier *et al.*1988 (c.33), Laurin (1991 B.2), Reisz *et al. (*1992 c.30), Berman *et al. (*1995 c.35), Rieppel (1999 c.9), Müller (2004 c.6), Reisz *et al. (*2010 c.24), Benson (2012 c.22).

This character was modified to include the septomaxilla to account for those taxa where the septomaxilla forms the posterior margin of the naris. The position of the septomaxilla in this respect is considered elsewhere (ch.22 above). State (1) of the present character is found in mycterosaurines (Botha-Brink and Modesto 2009, Reisz and Berman 2001), neodiapsids (Gow 1975, Bickelmann *et al. 2*009, Modesto and Sues 2004), ankyramorph parareptiles (Tsuji 2006, deBraga and Reisz 1996, Car- roll and Lindsey 1985) and derived sphenacodontids (Romer and Price 1940).

Unambiguous: Mycterosaurinae (0to1), *Deltavjatia rossicus* (1to0), Ankyramorpha (0to1), Neodiapsida (0to1), Sphenacodontidae + *Cutleria wilmarthi* (0to1)

51. Lacrimal, contribution to margin of external naris/septomaxilla: broad (0); narrow (1); inapplicable, contact absent (-)

Modified from Berman *et al. (*1995 c.36), Benson (2012 c.49).

Unambiguous: *Varanosaurus acutirostris* (0to1), Sphenacodontia (0to1), *Orovenator mayorum* (0to1)

52. Lacrimal, contribution to orbital margin as seen in lateral view: large, greater than 20% or more of the orbital circumference (0); moderate, between 8-16% of the orbital circumference (1); small less than 5% of the orbital circumference or absent, restricted by a prominent ventral process of the prefrontal (2)

Modified from Laurin (1993 c.32), Müller (2004 c.181), Maddin *et al. (*2006 c.16), Reisz *et al. (*2009 c.26), Fröbisch et *al. (*2011 c.25), Benson (2012 c.51).

The lack of quantitative criteria has led to inconsistencies among previous studies in scoring this character (e.g. Benson 2012 and Fröbisch et *al. 2*011 disagree in respect to *Secodontosaurus*, with Benson scoring as narrow, and Fröbisch et *al.* as large). In

Dimetrodon limbatus (Romer and Price 1940 plate 6) the contribution of the lacrimal to the orbital circumference is between 7 and 8% (state 1), and both the anterodorsal extension of the jugal and the ventral process of the prefrontal restrict the contribution of the lacrimal. In *Archaeovenator* the lacrimal is 'virtually excluded' from the orbital margin (state 2)(Reisz and Dilkes 2003:671). In *Mesenosaurus* and *Mycterosaurus* the lacrimal is equally restricted from the orbital margin (Berman and Reisz 1982, Reisz and Berman 2001). In *Orovenator* lacrimal contribution is less than 4% (state 2)(OMNH 74606). In all the cases that share state (2) the ventral process of the prefrontal is the principle restricting element to the orbital contribution of the lacrimal. A similar morphology is seen in *Prolacerta* (Gow 1975), *Proterosuchus* (Ezcurra and Butler 2015) and *Macroleter* (Tsuji 2006). In the present study the scoring for state (2) of this character is applicable only to early varanopids and mycterosaurines, neodiapsids and some parareptiles. In diadectomorphs, caseids, 'protorothyridids', *Petrolacosaurus* and captorhinids there is a broad contribution of the lacrimal to the orbital rim (state 0).

Unambiguous: Varanodontinae (2to1), *Macroleter poezicus* (1to2), *Candelaria barbouri* (1to0), *Acleistorhinus pteroticus* (1to0), Parareptilia (2to1), Varanopidae + Neoreptilia (0to2), *Seymouria* spp (0to1), *Ianthasaurus hardestiorum* (1to0), *Araeoscelis* spp (0to1). DELTRAN: *Youngina capensis* (2to1), Eothyrididae (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (2to1), Synapsida (0to1), Caseidae (1to0)

53. Lacrimal, duct: opens on posterior (orbital rim) surface of lacrimal (0); opens laterally near posterior edge of lacrimal (1); opens laterally on concave surface of lacrimal (2); opens on a notch between the lateral and posterior (orbital) surface of the lacrimal (3)

From Reisz *et al. (*1998 c.19), Maddin *et al. (*2006 c.15), Reisz *et al. (*2009 c.25), Campione and Reisz (2010 c.15), Reisz *et al. (*2010 c.25), Benson (2012 c.52), Spindler *et al. (*2018 c.34).

The position of the anterior opening(s) of the lacrimal duct is primitively found on the posterior surface (orbital rim) of the lacrimal (state 0). In mycterosaurines, *Acerosodontosaurus*, *Prolacerta* and some parareptiles the opening is located instead on the posterolateral surface of the lacrimal, and so can be seen lateral view. Reisz *et al. (*1998) considered that the condition in varanodontines (*Aerosaurus* + *Varanops* + *Varanodon*), with an opening more anteriorly placed within the concavity on the surface of the lacrimal, was sufficiently different to warrant a third state (state 2). This scoring was followed in all subsequent studies until Spindler *et al. (*2018), where the presence of state (2) in any varanodontine was questioned. Campione and Reisz (2010) noted the exit of the lacrimal duct was via the infraorbital foramen located on the orbital rim of *Varanops*, yet maintained the scoring of this taxon as state (2) in the same study (Campione and Reisz 2010 c.15). Based on the examination of the holotype and two referred specimens of *Varanops* (FMNH UC 644, MCZ 1926, FMNH UR 2423) we concur with Campione and Reisz in the location of the exit foramen for the lacrimal duct being on the orbital rim (state 0) in *Varanops*, and score this taxon accordingly herein. In *Mesosaurus tenuidens* the opening takes the form of a notch that is located on the angle between the lateral and posterior surface of the lacrimal (Modesto 2006), and is herein scored separately from other taxa (state 3). *Mesosaurus* is the only operational unit to be scored with this states, and although parsimony uninformative, is retained for information purposes.

DELTRAN: Mycterosaurinae (0to1), Neodiapsida except *Claudiosaurus* (0to1), *Belebey vegrandis* (0to1), *Mesosaurus tenuidens* (0to3), *Varanodon agilis* (0to2), *Aerosaurus wellesi* (0to2). ACCTRAN: Varanodontinae (1to2), Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), Parareptilia except Mesosauridae and Bolosauria (1to0), Mesosauridae (1to3), Neoreptilia (0to1), *Varanops brevirostris* (2to0)

54. Lacrimal, contact with jugal in lateral view: present (0); absent and maxilla participates in orbital margin (1)

Modified from Reisz 1986 (table 3a), Benson (2012 c.72).

In most of the taxa considered in the present study, including varanodontines (e.g. *Aerosaurus*, Langston and Reisz 1981, *Varanops*, FMNH UR 2423 and *Varanodon*, FMNH UR 986), the lacrimal contacts the anterior process of the jugal either anteroventral or ventral to the orbit (state 0). This contact excludes the maxilla from participating in the rim of the orbit. In contrast to this, in the eothyridids *Eothyris* and *Vaughnictis* the short anterior process of the jugal does not meet the lacrimal and the maxilla contributes substantially to the ventral margin of the orbit (state 1)(MCZ 1161, Reisz *et al. 2*009 and MCZ 2985, Brocklehurst *et al. 2*016). In *Orovenator* (Reisz *et al. 2*011) and *Mesenosaurus* (Reisz and Berman 2001) the jugal and lacrimal also do not meet in lateral view (state 1). Instead contact between these two elements is medial to the maxillary orbital margin in these taxa (Reisz and Berman 2001, Ford and Benson 2018). In *Archaeovenator*, contact between the jugal and lacrimal is likely (Reisz and Dilkes 2003), but this would probably have also been medial to the maxillary orbital margin given the dorsoventrally high ‘up-step’ in the anterior suborbital ramus of the maxilla, morphology very similar to that of *Orovenator*. *Archaeovenator* is accordingly scored as state (1) herein. In *Mycterosaurus*, jugal/lacrimal contact is uncertain since the lacrimal is poorly preserved (Berman and Reisz 1982), as is the case in other mycterosaurines (e.g. *Elliotsmithia*, Reisz *et al.*1998 and *Heleosaurus*, Botha-Brink and Modesto 2009).

Unambiguous: *Claudiosaurus germaini* (0to1), *Nyctiphruretus acudens* (0to1), *Milleretta rubidgei* (0to1), *Eothyris parkeyi* + *Eocasea martini* + *Vaughnictis smithae*

(0to1). DELTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Mesenosaurus romeri* (0to1). ACCTRAN: Varanodontinae (1to0), Varanopidae except *Ascendonanus* (0to1)

55. Lacrimal, suture with jugal in lateral view: small, less than 50% of the minimum dorsoventral height of the suborbital bar (0); well developed, greater than 50% of the minimum dorsoventral height of the suborbital bar (1); inapplicable, lateral contact absent (-)

Modified from Dodick and Modesto (1995 c.4), Modesto *et al. (*2007 c.5), Sumida *et al. (*2010 c.7), Modesto *et al. (*2018 c.13).

Unambiguous: Reptilia except Captorhinidae (1to0), *Seymouria* spp (1to0). DELTRAN: *Belebey vegrandis* (0to1), *Oedaleops campi* (1to0), *Euromycter rutena* (1to0).ACCTRAN: Bolosauria (0to1), *Ennatosaurus tecton* (0to1), Caseasauria (1to0)

56. Prefrontal, contact with postfrontal: contact of prefrontal and postfrontal excludes the frontal from the dorsal margin of the orbit (0); prefrontal and postfrontal separated by the frontal along the dorsal margin of the orbit (1)

Modified from Laurin and Reisz (1995 c.2), deBraga and Rieppel (1997 c.22), Rieppel (1999 c.10), Müller (2004 c.7), Tsuji (2006 c.2), MacDougall and Reisz (2014 c.3), Modesto *et al. (*2015 c.3).

Character state (0) is present in diadectomorphs, *Seymouria* and *Gephyrostegus* in the current taxon list, and convergently in *Deltavjatia rossicus* (Tsuji 2013). *Eothyris* has a very narrow lappet, less than 1mm in width, separating the pre- and postfrontals (Reisz *et al. 2*009, MCZ 1161).

Unambiguous: *Deltavjatia rossicus* (1to0), Amniota (0to1)

57. Prefrontal, contact with counterpart on the midline of the skull roof: absent (0); present (1)

From Cisneros *et al.* (2004 c.18)

Character state 1 is a synapomorphy of owenettids.

Unambiguous: Owenettidae (0to1)

58. Prefrontal, palatal contact: absent (0); present (1)

Modified from Wu and Chatterjee (1993 c.10), Laurin and Reisz (1995 c.6), Reisz *et al. (*1998 c.7), Reisz *et al. (*2007 c.6), MacDougall and Reisz (2014 c.11), Modesto *et al. (*2015 c.11).

State (1) of this character is present in most parareptiles (Laurin and Reisz 1995), mycterosaurines (Berman and Reisz 1982, Reisz and Berman 2001), *Orovenator* (Ford and Benson 2018) and *Edaphosaurus* (Modesto 1995) in the current taxon list. State (1) has also been considered as present in captorhinids in some studies (e.g. Laurin and Reisz 1995, Modesto 2015). However, Heaton (1979 fig.9) noted that the sutural scar on the medial surface of the lacrimal for the prefrontal is dorsal to the sutural contact with the palatine in *Captorhinus laticeps*. It is also interesting to note that phylogenetic datasets focusing in captorhinids do not include this character (e.g. Modesto *et al. 2*018, Sumida *et al. 2*010, Dodick and Modesto 1995). Consequently captorhinids are scored as (0) herein.

Unambiguous: Parareptilia except Mesosauridae (0to1), *Seymouria* spp (0to1), *Edaphosaurus boanerges* (0to1). DELTRAN: Mycterosaurinae (0to1), *Captorhinus aguti* + *Captorhinus laticeps* (0to1), *Orovenator mayorum* (0to1). ACCTRAN: Varanodontinae (1to0), Varanopidae (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1)

59. Prefrontal, width of palatal contact: narrow, forming less that one third of the transverse distance between the orbits (0); wide, forming at least one half of the distance (1); inapplicable, palatal contact absent (-)

Modified from Laurin and Reisz (1997 c.7), deBraga and Rieppel (1997 c.20), Müller (2004 c.130), Modesto *et al. (*2015 c.12/13).

This character differentiates between the prefrontal/palatal contact in parareptiles, which takes the form of a mediolaterally wide flange (state 1) and the more transversely narrow morphology in all other taxa (state 0).

DELTRAN: Parareptilia except Mesosauridae (0to1). ACCTRAN: Neoreptilia (0to1)

60. Prefrontal, suture with nasal: parasagittal, at least in its caudal third (0); anterolateral (1)

Modified from Laurin (1991 E.1), Reisz *et al. (*2010 c.33), Ezcurra *et al. (*2014 c.32), Pritchard *et al. (*2015 c.9), Piñeiro *et al. (*2016 c.38).

An anterolaterally orientated suture of the nasal and prefrontal was considered as a synapomorphy of the Sauria by Laurin (1991). However, Ezcurra *et al. (*2014) observed that it was also present in non-saurian neodiapsids (*Youngina* BP/1/3859). It is also present in *Lanthanolania* (Modesto and Reisz 2003) and *Claudiosaurus* (Carroll 1981).

Unambiguous: Neodiapsida except *Claudiosaurus* (0to1)

61. Prefrontal, lateral surface: approximately flat or convex (0); concave,

forming antorbital recess (prefrontal pocket) (1)

Reisz *et al. (*1992 c.9), Berman *et al. (*1995 c.12), Laurin (1993 c.11), Fröbisch et *al. (*2011 c.10), Benson (2012 c.54), Spindler *et al. (*2018 c.38).

Unambiguous: *Proterosuchus* spp (0to1). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontia (0to1). ACCTRAN: Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

62. Prefrontal, sharp angle between the dorsal and lateral surface: absent (0), present (1)

NEW

In ophiacodontids (*Varanosaurus* FMNH PR 1670, *Ophiacodon uniformis* MCZ 5934), early varanopids, mycterosaurines and varanodontines (Reisz and Dilkes 2003, Berman and Reisz 2001, *Mycterosaurus* FMNH UC 692, Reisz *et al.*1998) the dorsal and lateral surfaces of the prefrontal meet at an angle of around 90 degrees, rather than transitioning gradually. This morphology is also present in *Orovenator* (Ford and Benson 2018).

DELTRAN: Varanopidae except *Ascendonanus* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: Varanopidae (0to1), Ophiacodontidae (0to1)

63. Frontal, contribution to orbital margin: narrow (0); broad, >1/4 of maximum orbital length (1); inapplicable, frontal does not contribute to orbital margin (-)

Modified from Reisz *et al. (*1992 c.11), Reisz *et al. (*1998 c.13), Reisz and Dilkes (2003 c.13), Maddin *et al. 2*006 c.18, Reisz *et al. 2*009 c.19, Reisz *et al. (*2010 c.26), Benson (2012 c.60), Spindler *et al. (*2018 c.40).

This character deals with the anteroposterior length of the frontal contribution to the orbital margin rather than the morphology of the frontal, i.e. if the orbital exposure is provided by a distinct lateral lappet of the frontal (see ch.64 below). A narrow frontal exposure is plesiomorphic for amniotes (caseasaurs and captorhinids). Parareptiles, notably *Mesosaurus* (Piñeiro *et al. 2*012) and some ankyramorphs (Tsuji 2006, *Acleistorhinus* FMNH UR 1038, Carroll and Lindsey 1985), are also scored for state (0), probably representing a reversal.

Unambiguous: *Ascendonanus nestleri* (1to0), *Candelaria barbouri* (0to1), Mesosauridae (1to0), Reptilia except Captorhinidae (0to1), *Ennatosaurus tecton* (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). DELTRAN: *Macroleter poezicus* (1to0), *Nyctiphruretus* + Procolophonoidea (1to0), *Acleistorhinus pteroticus* (1to0). ACCTRAN: *Emeroleter levis + Deltavjatia rossicus*

(0to1), *Colobomycter pholeter* (0to1), Ankyramorpha (1to0)

64. Frontal, contribution to orbital margin formed by lateral lappet: absent (0); present (1); inapplicable, frontal does not contribute to orbital margin (-)

Modified from Gauthier *et al. (*1988 c.8), Brinkman and Eberth (1983 c.10), deBraga and Reisz (1996 c.7), Tsuji (2006 c.3), MacDougall and Reisz (2014 c.5), Modesto *et al. (*2015 c.5), Spindler *et al. (*2018 c.41).

Brinkman and Eberth (1983) described the distinct lateral lappet of the frontal that contributes to the orbital margin in early synapsids as being greater in mediolateral width than the posterior region of the frontal. Reisz (1986) recognized a lateral expansion of the frontal contributing to the orbital margin in early synapsids. Benson (2012) omitted this character, concluding that the lappet formed a continuum in early synapsids, making scoring problematic. Indeed, for some datasets the presence of a lateral expansion of the frontal and the presence of a frontal contribution to the orbital rim are synonymous (e.g. Modesto 1995 c.9). In the current taxon list, however, this character forms a clear morphological dichotomy and provides salient phylogenetic data. Herein these two morphologies are considered as independent characters in accordance with more recent studies (Modesto *et al. 2*015 c.5, Spindler *et al. 2*018 c.41). State (1), the presence of a lateral lappet, has a broad distribution amongst early synapsids (Reisz 1986), although we concur with Brinkman and Eberth (1983) that it is absence in mycterosaurines and varanodontines. A large frontal lappet is considered an autapomorphy of lanthanosuchoid parareptiles (deBraga and Reisz 1996) (e.g. *Acleistorhinus* and *Colobomycter* in the current taxon list). The lappet is absent in 'protorothyridids', araeoscelidians, neodiapsids (with exception of *Claudiosaurus*), captorhinids (with exception of *Romeria texana, Labidosaurikos* and *Labidosaurus*) and most parareptiles.

Unambiguous: *Claudiosaurus germaini* (0to1), Lanthanosuchoidea (0to1), *Labidosaurikos meachami* + *Labidosaurus hamatus* (0to1), *Romeria* spp (0to1), Synapsida (0to1), *Ennatosaurus tecton* (1to0), *Varanosaurus acutirostris* (1to0)

65. Frontal, anteroposterior length at the midline: less than 1.5 times parietal length (0); equal to or greater than 1.5 times parietal length (1); greater than 2.5 times parietal length (2)

Modified from Sidor and Hopson (1998 c.47), Dilkes (1998 c.19), Maddin *et al. (*2008 c.25), Benson (2012 c.56).

The frontal is short anteroposteriorly relative to the parietal (state 0) in caseasaurs (Langston 1965, Reisz *et al. 2*009, *Casea broilii* FMNH UC 656, Maddin *et al. 2*008), captorhinids (*Captorhinus laticeps* FMNH UC 701, OMNH 15101, *Protocaptorhinus* *pricei* MCZ 1160, *Romeria* primus MCZ 1963, Reisz *et al.* 2016) and some parareptiles (Tsuji 2006, MacDougall *et al. 2*017, *Acleistorhinus pteroticus* FMNH UR 1038). Neodiapsids, varanopids and ophiacodontids are scored for state (1). Only sphenacodontids (Romer and Price 1940, Reisz *et al.*1992) and the archosauromorph *Proterosuchus* (Ezcurra and Butler 2015) possess the greatly enlarged frontals relative to the parietals (state 2) in the current taxon list.

Unambiguous: *Proterosuchus* spp (1to2), Owenettidae (0to1), *Labidosaurikos meachami* (0to1), Captorhinidae (1to0), *Seymouria* spp (1to0), Sphenacodontidae + *Cutleria wilmarthi* (1to2), *Edaphosaurus boanerges* (1to0), Caseasauria (1to0), *Hylonomus lyelli* (1to0). DELTRAN: *Belebey vegrandis* (1to0), Ankyramorpha (1to0), *Reiszorhinus olsoni* (0to1). ACCTRAN: *Milleretta rubidgei* (0to1), Parareptilia except Mesosauridae (1to0), *Romeria* spp + *Reiszorhinus olsoni* 0to1)

66. Frontal, posterolateral process: absent, frontoparietal suture forming right angle to parasagittal plane (0); short, only partially separating parietal from dorsolateral margin of postfrontal or forming obtuse posterolateral angle to parasagittal plane (1); long, narrow, frontoparietal suture forming acute posterolateral angle with parasagittal plane, substantially or fully separating parietal from dorsomedial margin of postfrontal (2)

Modified from Reisz *et al. (*1998 c.4), Rieppel (1999 c.15), Reisz and Dilkes (2003 c.4), Müller (2004 c.10) Maddin *et al. (*2006 c.17), Reisz *et al. (*2009 c.28), Reisz *et al. (*2010 c.27), Benson (2012 c.61), Spindler *et al. (*2018 c.39).

The character state 0 is found in *Seymouria* and *Gephyrostegus* (Klembara *et al. 2*005, 2014), captorhinids (*Protocaptorhinus pricei* MCZ 1478, Reisz *et al. 2*016) and 'protorothyridids' (Carroll 1964, 1969) and as a secondary reversal in sphenacodontids (Romer and Price 1940, Reisz *et al.*1992). An elongate posterolateral process of the frontal (state 2) is present in ophiacodontids, mycterosaurines, varanodontines, neodiapsids and some parareptiles. Most other taxa herein share state (1), including diadectomorphs (Moss 1972, Berman *et al. 2*010) and eothyridids (Langston 1965, Reisz *et al. 2*009, Brocklehurst *et al. 2*016).

Unambiguous: Diapsida (0to2), *Protorothyris archeri* (0to1), *Petrolacosaurus kansensis* (2to1).DELTRAN: *Belebey vegrandis* (2to0), *Nyctiphruretus acudens* (2to0), Pareiasauria + Nycteroleteridae (2to1), Lanthanosuchoidea (2to1), Diadectomorpha (0to1), Eothyrididae (0to1), Ophiacodontidae except *Echinerpeton* (0to2), *Haptodus garnettensis* (0to1), Edaphosauridae (0to1). ACCTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (2to0), Procolophonoidea (0to2), *Nyctiphruretus* + Procolophonoidea (1to0), Ankyramorpha (2to1), Reptilia (1to0), Amniota + Diadectomorpha (0to1), Caseidae (1to0), Sphenacodontia except *Haptodus* (1to0), Ophiacodontidae (1to2)

67. Frontal, anterior process length: short, not longer than the posterior process (0); longer than posterior process (1); very long, forming at least 2/3 of the anteroposterior length of bone (2)

From Benson (2012 c.59)

Unambiguous: *Prolacerta broomi* (0to1), Parareptilia except Mesosauridae (0to1), *Labidosaurikos meachami* (1to2), Reptilia (1to0), *Seymouria* spp (1to0), Sphenacodontidae (1to2), *Pantelosaurus saxonicus* (1to0), Edaphosauridae (1to0), 'protorothyridids' except *Hylonomus* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Emeroleter levis* + *Deltavjatia rossicus* (1to0), Owenettidae (1to0), *Nyctiphruretus acudens* (1to0), *Labidosaurus hamatus* (0to1), Protocaptorhinus pricei (0to1), *Reiszorhinus olsoni* (0to1), *Ennatosaurus tecton* (1to0), *Varanodon brevirostris* (0to1). ACCTRAN: *Macroleter poezicus* (0to1), *Procolophon trigoniceps* (0to1), Ankyramorpha except Lanthanosuchoidea (1to0), *Captorhinus aguti* + *Captorhinus laticeps* (1to0), *Romeria* spp (1to0), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), Caseidae (1to0), *Varanodon agilis* + *Watongia meieri* (0to1)

68. Postorbital, lateral tuberosity at orbital margin: absent (0); present (1)

Modified from Reisz *et al. (*1998 c.14), Reisz and Dilkes (2003 c.37), Maddin *et al. (*2006 c.23), Reisz *et al. (*2009 c.33), Reisz *et al. (*2010 c.44), Benson (2012 c.67), Spindler *et al. (*2018 c.47).

Character state 1, describing the presence of a freely exposed lateral boss on the prefrontal is present in most derived mycterosaurines and varanodontines (Botha-Brink and Modesto 2009, microCT data *Mycterosaurus longiceps* FMNH UC 692, Reisz and Laurin 2004) with the exception of early varanopids (Reisz *et al. 2*011, Spindler *et al. 2*018) and *Varanops* (Campione and Reisz 2010). It is also present in the parareptile *Macroleter poezicus (T*suji 2006). The raised area of bone on the postorbital of some sphenacodontians is scored as state (0) herein, following the comments of Spindler *et al. (*2018 c.47), who interpreted the raised ridge forming the orbital rim on the postorbital as a lateral extension supporting the postfrontal, and creating a vertical trough in the postorbital, rather than a freely exposed boss.

DELTRAN: Mycterosaurinae (0to1), *Deltavjatia rossicus* (0to1), *Macroleter poezicus* (0to1), *Varanodon agilis* + *Watongia meieri* (0to1). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), *Emeroleter levis (*1to0), Pareiasauria + Nycteroleteridae (0to1), *Varanops brevirostris* (1to0)

69. Postorbital, posterior process, contact with supratemporal: absent (0); present (1)

Modified form Reisz *et al. (*1992 c.20), Laurin (1993 c.25), Laurin and Reisz (1995 c.12), Berman *et al. (*1995 c.26), deBraga and Rieppel (1997 c.30), Maddin *et al. (*2008 c.27), Fröbisch et *al. (*2011 c.19), Benson (2012 c.66), Modesto *et al. (*2015 c.22), Spindler *et al. (*2018 c.49).

Contact between the postorbital and supratemporal is absent (state 0) in *Seymouria*, *Gephyrostegus* and *Tseajaia* (Laurin 1996, Evans 1980, Moss 1972), although it is present (state 1) in *Limnoscelis* (Romer 1946, Berman *et al. 2*010). All araeoscelidians, neodiapsids and captorhinids in the current taxon list possess state (0), together with the parareptiles *Mesosaurus* (Modesto 2006, Piñeiro *et al.* 2012), *Stereosternum* (Modesto 1999) and *Belebey vegrandis* (where the supratemporal may be fused to the tabular – see Reisz *et al.* 2007). State (1) is found in all caseasaurs (e.g. *Eothyris* MCZ 1161, *Casea* FMNH UC 656), but varies within other groups. It is present in *Ophiacodon* (Romer and Price 1940), but absent in *Varanosaurus* (FMNH PR 1670), where a narrow process of the parietal separates the two bones. It is present in *Dimetrodon* and *Sphenacodon*, but absent in *Secodontosaurus* (Reisz *et al.*1992). It is present in *Archaeovenator* (Reisz and Dilkes 2003) but absent in *Mesenosaurus* (Reisz and Berman 2001) and *Ascendonanus* (Spindler *et al.* 2018).

Unambiguous: Varanopidae except *Ascendonanus* (0to1), Ankyramorpha (0to1), *Limnoscelis paludis* (0to1), *Ophiacodon* spp (0to1), *Dimetrodon* spp (0to1), Caseasauria (0to1), *Mesenosaurus romeri* (1to0)

70. Postorbital, anteroposterior length of posterior process: short (0); long, extending more than half of temporal length (1)

Modified from Laurin (1993 c.25), Berman (1995 c.25), Reisz *et al. (*1998 c.23), Maddin *et al.* (2006 c.21), Maddin *et al. (*2008 c.15), Reisz *et al. (*2009 c.31), Benson (2012 c.68), Spindler *et al. (*2018 c.45)

This character is considered independent to ch.69 above, since other factors can determine contact with the supratemporal e.g. *Mesenosaurus*, where the contact is absent but the posterior process is long (Reisz and Berman 2001), whereas in varanodontines the posterior process is short but still makes contact with the supratemporal (Campione and Reisz 2010).

Unambiguous: *Prolacerta broomi* (1to0), *Candelaria barbouri* (0to1), *Nyctiphruretus* + Procolophonoidea (1to0), *Limnoscelis paludis* (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontia except *Haptodus* (0to1). DELTRAN: *Mesosaurus tenuidens* (1to0), Varanopidae + Neoreptilia (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Caseasauria (0to1), *Araeoscelis* spp (0to1), Varanodontinae except *Aerosaurus wellesi* (1to0). ACCTRAN: Varanodontinae (1to0), Mesosauridae (1to0), Diapsida (0to1), Synapsida (0to1), Sphenacodontia + Edaphosauridae (1to0), *Petrolacosaurus kansensis* (1to0)

71. Postorbital, posterior process, transverse (dorsoventral) width: broad, at least 25% of dorsoventral height of temporal region (0); narrow, no more than 20% of dorsoventral height of temporal region (1)

Modified from Reisz *et al. (*1992 c.22), Laurin (1993 c.15), Berman (1995 c.26), Maddin *et al. (*2008 c.28), Fröbisch et *al. (*2011 c.13), Benson (2012 c.69), Spindler *et al. (*2018 c.46).

This character has been modified from that used in previous studies by quantifying the relative transverse width of the posterior process in relation to the height of the temporal region at the same level. This is a similar approach to that taken with the dorsoventral height of the ventral temporal (zygomatic) bar in ch.74 below.

Unambiguous: *Ascendonanus nestleri* (1to0), *Owenetta kitchingorum* (1to0), Lanthanosuchoidea (1to0), Diapsida (0to1), *Labidosaurikos meachami* (0to1), *Thuringothyris mahlendorffae* (0to1), Synapsida (0to1), *Eothyris parkeyi* + *Eocasea martini* (1to0), *Heleosaurus scholtzi* + *Mesenosaurus romeri* (1to0). DELTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (1to0). ACCTRAN: Bolosauria (1to0)

72. Postorbital, dorsal and lateral surfaces: form smooth curve (or dorsal surface absent, postorbital not participating in skull roof) (0); sharply divided (meeting at edge) (1)

Modified from Reisz *et al. (*1998 c.25), Reisz and Dilkes (2003 c.25), Maddin *et al. (*2006 c.22), Reisz *et al. (*2009 c.32), Reisz *et al. (*2010 c.43), Campione and Reisz (2010 c.22)

Recent studies have rejected a modified version of this character due to uncertainty of the distinction between states (Benson 2012 c.X1, Spindler *et al. 2*018). This character describes the same morphology for the postorbital as ch.62 above does for the prefrontal, and is coded as present in some mycterosaurines (Reisz and Berman 2001, Berman and Reisz 1982). Maddin *et al. (*2008:173) note that a 'well-defined right angle' between the skull table and temporal surface of the postorbital is present in derived caseasaurs such as *Ennatosaurus* and *Cotylorhynchus*.

Unambiguous: *Ennatosaurus tecton* (0to1), Mycterosaurinae (0to1).

73. Postorbital, contact with parietal: absent (0); present (1)

Modified from Dilkes (1998 c.22), Müller (2004 c.89).

The postorbital contacts the parietal in all terminal taxa in the present study with some exceptions. In *Seymouria* and *Gephyrostegus* the intertemporal bone prevents contact with the parietal (Klembara *et al. 2*005, 2014). A broad contact between the postfrontal and supratemporal in the parareptile *Acleistorhinus* prevents contact of the postorbital and parietal (deBraga and Reisz 1996). In archosauriforms, represented by *Proterosuchus* in the present study, postfrontal/supratemporal contact also excludes the postorbital from contact with the parietal (Ezcurra and Butler 2015).

Unambiguous; *Proterosuchus* spp (1to0), Owenettidae (1to0), *Acleistorhinus pteroticus* (1to0), Amniota + Diadectomorpha (0to1)

74. Temporal (=Postorbital) region, height of ventral temporal (zygomatic) bar (complete or partially complete): tall, occupying more than 20% of skull height (0); narrow, occupying less than 20% of postorbital skull height (1) inapplicable, ventral temporal bar absent (-)

Modified from Laurin (1991 B.4), Dilkes (1998 c.32), Reisz and Dilkes (2003 c.18), Müller (2004 91), Reisz *et al. (*2010 c.41), Ezcurra *et al. (*2014 c.40)

All neodiapsids, varanopids and parareptiles share state (1), describing a narrow ventral temporal bar. The ventral temporal bar of *Haptodus* (Laurin 1993) and edaphosaurids (Modesto 1995, Modesto and Reisz 1990) are also scored as narrow. caseasaurs, ophiacodontids and sphenacodontids possess tall ventral bars (state 0). The araeoscelidian diapsid *Petrolacosaurus* possess a relatively tall ventral bar (Reisz 1981, Reisz *et al. 2*010 c.41),

Unambiguous: *Milleretta rubidgei* (1to0), Varanopidae + Neoreptilia (0to1). DELTRAN: *Haptodus garnettensis* (0to1), Edaphosauridae (0to1). ACCTRAN: Sphenacodontia except *Haptodus* (1to0), Sphenacodontia + Edaphosauridae (0to1)

75. Postorbital, free dorsal margin: absent (0); present (1)

NEW

This character is the first of eight new characters coded to describe temporal fenestrae and emarginations. A free surface at any point on the dorsal margin of the postorbital (state 1) indicates the presence of an upper temporal fenestra, and is present in araeoscelidian diapsids, neodiapsids, and *Orovenator mayorum*.

Unambiguous: Neodiapsida (0to1), Araeoscelidia (0to1), *Orovenator mayorum* (0to1)

76. Jugal, free posterior margin: absent (0); present (1)

NEW

This character is the second of eight new characters coded to describe temporal fenestrae and emarginations. A free surface at any point on the posterior margin of the jugal (state 1) indicates the presence of a lateral temporal fenestration or emargination.

Unambiguous: *Emeroleter levis* + *Deltavjatia rossicus* (1to0), *Procolophon trigoniceps* (1to0), Synapsida (0to1). DELTRAN: *Mesosaurus tenuidens* (1to0), Varanopidae + Neoreptilia (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Mesosauridae (1to0), Diapsida (0to1), *Araeoscelis* spp (1to0)

77. Jugal, free concave ventral margin: absent (0); present (1)

NEW

This character is the third of eight new characters coded to describe temporal fenestrae and emarginations. Character state (1) describes the concavity on the ventral margin of the jugal that contributes to a distinct ventral emargination of the postorbital region in sphenacodontids (e.g. *Secodontosaurus* MCZ 1124, Reisz *et al.*1992; *Dimetrodon*, Romer and Price 1940; *Sphenacodon*, Spielmann *et al.* 2010), *Edaphosaurus* (Modesto 1995 fig.2/fig.6) and the parareptile *Procolophon* (Carroll and Lindsay 1985).

Unambiguous: *Edaphosaurus boanerges* (0to1), Sphenacodontidae (0to1), *Procolophon trigoniceps* (0to1).

78. Jugal, contribution to ventral margin of the skull: present (0); absent (1)

Modified from, Reisz *et al.* (1992 c.31), Berman (1995 c.37), Maddin *et al.* (2008 c.13), Benson (2012 c.71 in part).

The jugal is excluded from the ventral margin of the skull (state 1) in caseasaurs, *Mycterosaurus*, *Elliotsmithia*, varanodontines and some parareptiles. This exclusion of the jugal from the ventral margin is achieved in all cases by the contact of the maxilla with the quadratojugal. However, the nature of this contact derives from two distinct morphologies (Langston and Reisz 1981, Reisz 1986), which differ between and within these groups, and forms the basis of the subsequent character (ch.79).

Unambiguous: Mycterosaurinae + Varanodontinae (0to1), Caseasauria (0to1), *Heleosaurus scholtzi* + *Mesenosaurus romeri* (1to0). DELTRAN: *Belebey vegrandis* (0to1), Pareiasauria + Nycteroleteridae (0to1), Lanthanosuchoidea (0to1).

ACCTRAN: *Nyctiphruretus* + Procolophonoidea (1to0), *Milleretta rubidgei* (1to0), Parareptilia except Mesosauridae (0to1)

79. Jugal, if contribution to ventral margin of skull is absent: jugal excluded from ventral margin by maxilla-quadratojugal contact achieved by a long posterior extension of the maxilla (0); maxilla-quadratojugal contact achieved by long anterior extension of the quadratojugal (1); inapplicable, jugal contributes to ventral margin of skull (-)

Modified from Brinkman and Eberth (1983 c.2), Modesto (1994 c.6), Laurin and Reisz (1995 c.22), Tsuji (2006 c.22), Reisz *et al. (*2009 c.46), Reisz *et al. (*2010 c.46 in part), Benson (2012 c.71 in part), Modesto *et al. (*2015 c.31), Spindler *et al. (*2018 c.62).

A long posterior extension of the maxilla is present in *Vaughnictis* (Brocklehurst *et al. 2*016), varanodontines (Campione and Reisz 2010), *Mycterosaurus* (Berman and Reisz 1982) and *Acleistorhinus* (deBraga and Reisz 1986). In *Elliotsmithia* (Modesto *et al. 2*001), all other caseasaurs apart from *Vaughnictis* and parareptiles the quadratojugal possesses an extended anterior process, which meets the maxilla closer to the orbital margin.

Unambiguous: *Emeroleter levis (*1to0), *Acleistorhinus pteroticus* (1to0), *Vaughnictis smithae* (1to0). DELTRAN: Varanodontinae (1to0), *Mycterosaurus longiceps* (1to0). ACCTRAN: Varanopidae (1to0), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1)

80. Jugal, suborbital ramus: does not extend to anterior orbital rim (0); extends at least to level of anterior orbital rim (1)

From Laurin and Reisz (1995 c.11), Tsuji (2006 c.12), Tsuji *et al. (*2012 c.12), MacDougall and Reisz (2014 c.18), Modesto *et al. (*2015 c.18), Modesto *et al. (*2018 c.20).

This character has typically been used in parareptile phylogenies, where state (1) is present in *Macroleter*, pareiasaurs and procolophonoids (Modesto *et al. 2*015). Modesto *et al. (*2015) also score araeoscelidians and neodiapsids as possessing state (1). However, the ramus does not extend to the anterior orbital rim in *Petrolacosaurus* (Reisz 1981, KUVP 9952), *Youngina* (BP/1/2871, FMNH UC 1528) and *Acerosodontosaurus* (Bickelmann *et al. 2*009). In derived ophiacodontids, sphenacodontians and some captorhinids the ramus extends beyond the anterior orbital rim (state 1). Among stem-amniotes, a short ramus is present in *Tseajaia* and *Gephyrostegus* (state 0) and the ramus length is polymorphic among species of *Seymouria* e.g. *S. baylorensis* shows state (0) (Laurin 1996), and *S. sanjuanensis* shows state (1) (Klembara *et al. 2*005). Spindler *et al. (*2018) rejects the concept of describing the anterior extent of the suborbital ramus by its relative position to the orbit as interdependent with proportional constraints, opting instead for the presence or absence of contact with the lacrimal (Spindler *et al. 2*018 online resource 3 c.44). However, we find that the scores of this character are independent of the scores of characters concerned with the lacrimal/jugal contact and extent of the suture (ch.54 and ch.55 above), and therefore use all of these characters in the study.

Unambiguous: *Proterosuchus* spp (0to1), *Procolophon trigoniceps* (0to1), Pareiasauria + Nycteroleteridae (0to1), Protocaptorhinus pricei (1to0), *Romeria* spp (1to0), Captorhinidae (0to1), *Limnoscelis paludis* (0to1). DELTRAN: *Mesosaurus tenuidens* (0to1), Ophiacodontidae except *Echinerpeton* (0to1), Sphenacodontia (0to1). ACCTRAN: Mesosauridae (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

81. Jugal, anteroposterior thickness of dorsal ramus (forming postorbital bar): broad, temporal fenestra only weakly emarginates the jugal (0); narrow, (1); inapplicable, temporal fenestration absent or jugal lacks dorsal ramus (-)

From Benson (2012 c.73) modified from Maddin *et al. (*2008 c.20), Reisz and Fröbisch (2014 c.73).

State (0) of this character is present in most early caseasaurs (Reisz *et al. 2*009, Brocklehurst *et al.* 2016, Reisz and Fröbisch 2014) and those parareptiles in which temporal fenestration is present (Tsuji 2006, MacDougall *et al. 2*017, deBraga and Reisz 1996)

DELTRAN: Parareptilia except Mesosauridae and Bolosauria (1to0), *Eothyris parkeyi* + *Eocasea martini* + *Vaughnictis smithae* (1to0), *Euromycter rutena* (1to0), Casea broilii (1to0). ACCTRAN: Parareptilia (1to0), *Oedaleops campi* (0to1), *Ennatosaurus tecton* (0to1), Caseasauria (1to0)

82. Jugal, posterior ramus length: long, extending to the posterior end of temporal fenestra (or past temporal midlength in taxa that lack a temporal fenestra) (0); short, extending to, or less than, temporal midlength (1); inapplicable, jugal lacks posterior process (-)

Modified from Gauthier *et al. (*1988 c.34), deBraga and Rieppel (1997 c.33), Rieppel (1999 c.24), Müller (2004 c.16), Reisz *et al. (*2009 c.49), Benson (2012 c.75).

Unambiguous: Mycterosaurinae (1to0), *Proterosuchus* spp (1to0), *Romeria* spp + *Reiszorhinus olsoni* (1to0), Amniota (0to1), *Eothyris parkeyi* (1to0), *Oedaleops campi* (1to0), *Dimetrodon* spp (1to0), *Pantelosaurus saxonicus* (1to0). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (1to0). ACCTRAN: Ophiacodontidae (1to0)

83. Jugal, tuberous ornamentation on lateral surface: absent (0); present (1)

Modified from Reisz *et al.*1998 c.14, Reisz and Dilkes 2003 c.17, Maddin *et al. 2*006 c.44, Reisz *et al. 2*010 c.34, Benson (2012 c.12).

Distinctive ornamentation in the form of a series of dorsoventral serrations on the ventral margin of the suborbital ramus of the jugal is present in *Aerosaurus* (Langston and Reisz 1981). A similar pattern on the ventral margin of the jugal is present in *Varanops*, although it is absent in *Varanodon* (Campione and Reisz 2010, FMNH UR 986). *Heleosaurus*, *Elliotsmithia* and *Mesenosaurus* also possess tubercular ornamentation on the lateral surface of the jugal (Reisz and Modesto 2007, Reisz *et al.*1998, Reisz and Berman 2001), and a small irregular raised ridge is present on the orbital margin of the left jugal in *Mycterosaurus*, based on microCT data of the holotype FMNH UC 692). Reisz *et al. (*2010) noted a small tubercle on the left jugal in *Apsisaurus*, although this appears to be absent from the right jugal (MCZ 1474). Circumorbital ornamentation is absent in the early varanopids *Archaeovenator* and *Ascendonanus* (Reisz and Dilkes 2003, Spindler *et al. 2*018).

Unambiguous: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1). DELTRAN: *Varanodon agilis* (1to0). ACCTRAN: *Varanodon agilis* + *Watongia meieri* (1to0)

84. Jugal, ventral contact with squamosal perforated by small elongate fenestra: absent (0); present, upper margin enclosed by anteroventral extension of the squamosal (1); inapplicable jugal does not contact squamosal ventrally (-)

From Benson (2012 c.76), modified from Berman *et al. (*1995 c.17)

A small 'half moon' shaped fenestra has been observed in some specimens of *Ophiacodon retroversus* at the junction of the squamosal, jugal and quadratojugal, which appears to be polymorphic for this genus (Romer and Price 1940). A similar condition is present in the only specimen of *Varanosaurus* where the temporal region is preserved (Berman *et al.*1995, FMNH PR 1670).

Unambiguous: *Varanosaurus* + *Ophiacodon* (0to1).

85. Quadratojugal, contact with posteroventral margin of jugal: present (0); absent (1)

NEW

This character is the fourth of eight new characters coded to describe temporal fenestrae and emarginations. The quadratojugal is in contact with the posteroventral margin of the jugal (state 0) in most taxa included in the present study, and this state is universally associated with the presence of an anteroventral process of the quadratojugal. Contact between the quadratojugal and posteroventral margin of jugal is absent (state 1) in all taxa included herein that possess an emargination or concavity of the ventral surface of the temporal region (e.g. sphenacodontians, edaphosaurids, some neodiapsids and owenettids), with the exception of *Procolophon*, in which the quadratojugal contacts the jugal along the entire posterior margin and is scored as state (0). This character replaces a character used in recent studies describing the presence, absence or size limitation of the anterior process of the quadratojugal (e.g. Benson 2012 c.77, Pritchard *et al. 2*015 c.39, Spindler *et al. 2*018 c.60).

Unambiguous: *Youngina capensis* (1to0), Neodiapsida (0to1), Sphenacodontia + Edaphosauridae (0to1). DELTRAN: Owenettidae (0to1), *Nyctiphruretus acudens* (0to1). ACCTRAN: *Procolophon trigoniceps* (1to0), *Nyctiphruretus* + Procolophonoidea (0to1)

86. Quadratojugal, contact with posterodorsal margin of jugal: absent (0); present (1)

NEW

This character is the fifth of eight new characters coded to describe temporal fenestrae and emarginations. Contact between the quadratojugal and the posterodorsal margin of the jugal is present (state 1) in procolophonoids (e.g. *Procolophon*, *Owenetta* and *Candelaria*) and *Nyctiphruretus*, and absent (state 0) in all other taxa.

Unambiguous: *Nyctiphruretus* + Procolophonoidea (0to1)

87. Quadratojugal, shape of anterior margin of anteroventral process: square-tipped (0); acuminate (tapering to a point) (1); inapplicable, anteroventral process absent (-)

From Dodick and Modesto 1995 c.10, Müller and Reisz (2005 c.10), Müller et *al. (*2006 c.10), Müller and Reisz (2006 c.10), Modesto *et al. (*2007 c.12), Modesto *et al. (*2018 c.23).

The anterior tip of the quadratojugal in the out-group taxon *Gephyrostegus* meets the jugal in a dorsoventrally straight suture (Klembara *et al. 2*014). The same condition is found in early 'protorothyridids' e.g. *Hylonomus* (Carroll 1964 - based on the morphology of jugal and squamosal) and *Cephalerpeton* (Carroll and Baird 1972), and some captorhinids e.g. *Romeria* primus (Clark and Carroll 1973) and *Captorhinus aguti* (Fox and Bowman 1966). *Ennatosaurus* (Maddin *et al. 2*008) and

Milleretta rubidgei (Gow 1972) also share state (0).

Unambiguous: *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Ennatosaurus tecton* (1to0), *Hylonomus lyelli* (1to0). DELTRAN: *Emeroleter*

*levis (*1to0), *Macroleter poezicus* (1to0), *Milleretta rubidgei* (1to0), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (1to0), *Romeria* spp + *Reiszorhinus olsoni* (1to0). ACCTRAN: *Deltavjatia rossicus* (0to1), Lanthanosuchoidea (0to1), Parareptilia except Mesosauridae and Bolosauria (1to0), Protocaptorhinus pricei (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (1to0)

88. Postorbital cheek: relatively straight (0); moderately expanded laterally (1)

Modified from Modesto *et al.* (2007 c13), Reisz *et al.* (2011 c.14), Modesto *et al.* (2014 c.26), Modesto *et al.* (2018 c.26)

State 1 of this character describes the lateral expansion of the postorbital cheek present in derived captorhinids, e.g. *Captorhinus aguti, Captorhinus laticeps, Labidosaurikos* and *Labidosaurus* (Modesto 1998, Heaton 1979, Dodick and Modesto 1995, Modesto *et al.* 2007). A lateral expansion of the postorbital cheek is also present in diadectomorphs. Some parareptiles, e.g. Procolophon and Deltavjatia, are also scored as state 1, due to the lateral projection of the quadratojugal.

Unambiguous: *Deltavjatia rossicus* (0to1), *Procolophon trigoniceps* (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (0to1), Diadectomorpha (0to1)

89. Squamosal, contacts posterodorsal margin of jugal: present (0); absent (1)

NEW

This character is the sixth of eight new characters coded to describe temporal fenestrae and emarginations. State (0) is present in all taxa that do not possess a lateral temporal opening, the anapsid condition (e.g. diadectomorphs, *Seymouria*, *Gephyrostegus*, 'protorothyridids', *Araeoscelis*, captorhinids and *Mesosaurus*), and in some that do, such as derived varanodontines (e.g. *Varanops*, *Varanodon*) and parareptiles (e.g. bolosaurs and *Acleistorhinus*)

Unambiguous: *Procolophon trigoniceps* (0to1), *Colobomycter pholeter* (0to1), *Milleretta rubidgei* (0to1), Synapsida (0to1), Varanodontinae except *Aerosaurus wellesi* (1to0). DELTRAN: Neodiapsida (0to1), Varanopidae (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Parareptilia (1to0), Diapsida (0to1), *Araeoscelis* spp (1to0)

90. Squamosal, contacts posteroventral margin of jugal: absent (0); present (1)

NEW

This character is the seventh of eight new characters coded to describe temporal fenestrae and emarginations. State (1) is present in eothyridids, ophiacodontids, sphenacodontians, edaphosaurids, mycterosaurines and bolosaurid parareptiles. It is also present in some anapsid taxa where the anterior region of the quadratojugal tapers to a point contact with the jugal, permitting the squamosal to contact the posteroventral margin of the jugal (e.g. *Paleothyris, Protorothyris*) and in *Araeoscelis*. In all taxa scoring as state (1) the quadratojugal does not participate in the lateral temporal fenestration (if present). Therefore, this character replaces a character used in several studies to describe the contribution of the quadratojugal to the lateral temporal fenestra (e.g. Tsuji 2006 c.32, Benson 2012 c.77/78 in part, MacDougall and Reisz 2014 c.46, Modesto *et al. 2*015 c.46, Spindler *et al. 2*018 c.61).

Unambiguous: Varanodontinae (1to0), Protocaptorhinus pricei (0to1), *Paleothyris acadiana* + *Protorothyris archeri* (0to1). DELTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), *Mesosaurus tenuidens* (0to1), Varanopidae (0to1), Eothyrididae (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1), *Araeoscelis* spp (0to1). ACCTRAN: Parareptilia except Mesosauridae and Bolosauria (1to0), Neodiapsida (1to0), Diapsida (0to1), Synapsida (0to1), Caseidae (1to0), *Petrolacosaurus kansensis* (1to0)

91. Squamosal, anteroposterior breadth of post-fenestral portion on lateral surface of skull: narrow (0); broad, just over half the breadth of the temporal region, restricting the posterior extent of the temporal fenestra (1); inapplicable, temporal fenestra absent (-)

From Benson (2012 c.79), modified in Spindler *et al. (*2018 c.55).

Ophiacodontids possess an anteroposteriorly broad region of the squamosal posterior to the temporal fenestra (state 1) (Romer and Price 1940, Berman *et al.*1995, Modesto and Reisz 1990). State (1) is also present in the eothyridid *Vaughnictis* (Brocklehurst *et al. 2*016), and some parareptiles (e.g. *Macroleter poezicus*, Tsuji 2006 and *Belebey*, Reisz *et al. 2*007).

Unambiguous: *Vaughnictis smithae* (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Macroleter poezicus* (0to1), *Milleretta rubidgei* (0to1), Ophiacodontidae except *Echinerpeton* (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (0to1), Ankyramorpha (1to0), Parareptilia (0to1), Ophiacodontidae (0to1)

92. Squamosal, occipital shelf (flange): mediolaterally broad, contributes to occipital surface of skull, obscuring much of the posterior margin of the quadrate (0); absent or mediolaterally very narrow, posterior margin of quadrate exposed in occipital view (1)

Modified from Laurin (1991 D.2, E.4), Berman *et al. (*1995 c.48), Laurin and Reisz (1995 c.27), deBraga and Rieppel (1997 c.37), Reisz *et al. (*1998 c.15), Reisz and Dilkes (2003 c.33), Müller (2004 c.132), Maddin *et al. (*2006 c.35), Reisz *et al. (*2009 c.39), Reisz *et al. (*2010 c.38), Benson (2012 c.80), Spindler *et al. (*2018 c.59).

Many early amniotes have a mediolaterally broad occipital flange of the squamosal e.g. captorhinids (Heaton 1979 fig.1, Sumida *et al. 2*010 fig.3), 'protorothyridids' (Clark and Carroll 1973 fig.2), caseasaurs (Reisz *et al. 2*009 fig.4, Maddin *et al. 2*008 fig.1) and early synapsids (Berman *et al.*1995 fig.9, Romer and Price 1940 plate 14, Modesto *et al.*1995 fig.1). In mycterosaurines (Reisz and Berman 2001 fig.4, Berman and Reisz 1982 fig.5), varanodontines (FMNH UR 986), *Araeoscelis* (Vaughn 1955 fig.4), *Prolacerta* (Modesto and Sues 2004 fig.5) and some parareptiles (deBraga and Reisz 1996 fig.1, Modesto 2006 fig.2) the flange is narrower or is absent altogether.

Unambiguous: Procolophonoidea (1to0), Diapsida (0to1), *Tseajaia campi* (0to1). DELTRAN: *Belebey vegrandis* (1to0), *Milleretta rubidgei* (1to0). ACCTRAN: Ankyramorpha (0to1), Parareptilia except Mesosauridae (1to0)

93. Squamosal, posterodorsal process: absent (0); present (1)

Modesto *et al. (*2001 c.33), Maddin *et al. (*2006 c.27), Reisz *et al. (*2009 c.40), Botha-Brink and Modesto (2009 c.27), Reisz *et al. (*2010 c.36), Benson (2012 c.81), Spindler *et al. (*2018 c.56).

Modesto *et al. (*2001) observed that a small spur of bone extending posteriorly from the posterodorsal corner of the squamosal in *Elliotsmithia* was also present in *Mesenosaurus* (state 1). Subsequently, the same morphology has been observed in *Heleosaurus* (Botha-Brink and Modesto 2009) and Spindler *et al. (*2018) noted a posterodorsal process in *Ascendonanus* (Spindler *et al. 2*018 fig.25). Several studies have also scored the derived state for caseasaurs (Maddin *et al. 2*006, Reisz *et al. 2*009, Spindler *et al. 2*018). We have not been able to determine the presence or absence of this feature in *Eothyris* (MCZ 1161) where the posterodorsal margin of the squamosal is obscured by the supratemporal, and we score this taxon as (?) herein. In *Oedaleops* there is a slight concavity in the posteroventral margin of the squamosal (Langston 1965 fig.1A), which does not represent the derived morphology of this character. A posterodorsal process of the squamosal is clearly present in the archosauromorphs *Prolacerta* (Modesto and Sues 2004) and *Proterosuchus* (Ezcurra and Butler 2015).

Unambiguous: *Ascendonanus nestleri* (0to1). DELTRAN: Archosauromorpha (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1).ACCTRAN: Mycterosaurinae (0to1), Neodiapsida except *Claudiosaurus* (0to1)

94. Squamosal, contribution to the posttemporal fenestra: absent (0); present (1)

Laurin and Reisz (1995 c.26), deBraga and Rieppel (1997 c.36), Müller and Reisz (2006 c.49), Tsuji (2006 c.26), Tsuji *et al. (*2012 c.25), Laurin and Piñeiro (2017 c.25).

This participation of the occipital flange of the squamosal in margin of the posttemporal fenestra is considered by several studies to be a synapomorphy of Eureptilia (Laurin and Reisz 1995, deBraga and Rieppel 1997, Laurin and Piñeiro2017). The mediolaterally broad occipital exposure of the squamosal in captorhinids and 'protorothyridids' (Fox and Bowman 1966, Carroll 1969, Clark and Carroll 1973, Müller et *al. 2*006) and in *Petrolacosaurus* (Reisz 1981), coupled with the absence of a tabular (in the case of most captorhinids) or an anteroposteriorly short tabular (in *Petrolacosaurus*), does allow an extensive exposure of the squamosal to the posttemporal fenestra (state 1). However, this is not the case in all early araeoscelidians, such as *Araeoscelis*, where the tabular is elongate (Vaughn 1955), or in the neodiapsid *Prolacerta*, where the occipital exposure of the squamosal in limited (Gow 1975, Modesto and Sues 2004). State (1) is also present, however, in some parareptiles (e.g., Modesto 2006; bolosaurids and *Acleistorhinus*, scoring of Tsuji 2006 c.26). In derived ophiacodontids, the squamosal forms the lateral margin of the posttemporal fenestra (state 1)(e.g. *Ophiacodon uniformis*, Romer and Price 1940 pl.4, and *Varanosaurus*, Berman *et al.*1995).

Unambiguous: Reptilia (0to1), *Araeoscelis* spp (1to0). DELTRAN: Mycterosaurinae + Varanodontinae (1to0), *Prolacerta broomi* (1to0), Ankyramorpha except Lanthanosuchoidea (1to0), *Milleretta rubidgei* (1to0), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (1to0), Lanthanosuchoidea (0to1), Parareptilia except Mesosauridae and Bolosauria (1to0), Varanopidae (1to0), Ophiacodontidae (0to1)

95. Parietal, free lateral margin: absent (0); present (1)

NEW

This character is the eighth of eight new characters coded to describe temporal fenestrae and emarginations. State (1) is present in all araeoscelidian diapsids, neodiapsids and *Orovenator mayorum*, in which it describes the morphology of the dorsal arcade of the upper temporal fenestra. It is also present in the early synapsids *Secodontosaurus* (Reisz *et al.*1992) and *Edaphosaurus* (Modesto 1995).

Unambiguous: Neodiapsida (0to1), Araeoscelidia (0to1), *Secodontosaurus obtusidens* (0to1), *Edaphosaurus boanerges* (0to1), *Orovenator mayorum* (0to1)

96. Parietal, anteroposterior diameter of pineal foramen: small, less than 25% of mid-parietal length (0); large, more than 25% of mid-parietal length (1); absent (2)

Modified from Gauthier *et al. (*1988 c.17), Reisz *et al. (*1992 c.17), Berman *et al. (*1995 c.22), Müller (2004 c.12), Reisz *et al. (*2009 c.84), Reisz *et al. (*2010 c.31), Benson (2012 c.35), Spindler *et al. (*2018 c.52).

A proportionally large pineal foramen is present in all caseasaurs (Olson 1968, Reisz *et al. 2*009) and ophiacodontids (Romer and Price 1940, FMNH PR 1670, MCZ 4070), most ankyramorph parareptiles, some mycterosaurines (Reisz and Berman 2001, Berman and Reisz 1982), *Aerosaurus* (Langston and Reisz 1981) and *Secodontosaurus* (MCZ 1124).

Unambiguous: Ankyramorpha except Lanthanosuchoidea (0to1), *Tseajaia campi* (0to1), *Dimetrodon* spp (1to0), Sphenacodontia except *Haptodus* (0to1). DELTRAN: Mycterosaurinae (0to1), *Claudiosaurus germaini* (0to1), *Belebey vegrandis* (0to1), Mesosauridae (0to1), Ophiacodontidae except *Echinerpeton* (0to1), Caseasauria (0to1), *Aerosaurus wellesi* (0to1). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), Neodiapsida except *Claudiosaurus* (1to0), Parareptilia except Mesosauridae and Bolosauria (1to0), Neoreptilia (0to1), Synapsida (0to1), Sphenacodontia + Edaphosauridae (1to0), Varanodontinae except *Aerosaurus wellesi* (1to0)

97. Parietal, pineal foramen location: anteriorly on parietal midline suture, such that the anterior rim of the foramen lies within the anterior third of the midline suture (0); midlength on parietal midline suture, such that the anterior and posterior rims of the foramen both lie within the middle third of the midline suture (1); posteriorly on parietal midline suture, such that the posterior rim of the foramen lies within the posterior third of the midline suture (2)

Modified from Reisz (1986 table 3.b), Laurin (1993 c.20), Modesto (1994 c.13), Laurin and Reisz (1995 c.3), deBraga and Rieppel (1997 c.47), Reisz *et al. (*1998 c.17), Rieppel (1999 c.18), Müller (2004 c.12), Maddin *et al. (*2006 c.20), Maddin *et al. (*2008 c.26), Reisz *et al. (*2009 c.35), Fröbisch et *al. (*2011 c.17), Benson (2012 c.85), Schoch and Sues (2015 c.49), Pritchard *et al. (*2015 c.23), Modesto *et al. (*018 c.28), Spindler *et al. (*2018 c.51).

This character has been used in various forms from the earliest cladistic analyses of 'pelycosaur'- grade synapsids, (e.g. Reisz 1986 table 3b) to the most recent analyses of captorhinids and synapsids (e.g. Modesto *et al. 2*018 c.28 and Spindler *et al. 2*018 c.51). Here, the definitions of the character states are clarified based on the position of the rim of the foramen in respect to the midline suture. We agree with the conclusion of Reisz (1986) that a posteriorly located foramen (state 2) is a synapomorphy of ophiacodontids, sphenacodontians, edaphosaurids and varanopids. State (2) is also shared with *Paleothyris*(MCZ 3483), *Orovenator* (Reisz *et al. 2*011), *Youngina* (BP/1/, 3895) and some parareptiles (*Macroleter poezicus*, Tsuji 2006, *Belebey*, Reisz *et al. 2*007). Captorhinids are united by an anteriorly placed foramen, as are caseids. Eothyridids share a centrally placed foramen as noted by Langston (1965).

Unambiguous: *Emeroleter levis + Deltavjatia rossicus* (2to0), Procolophonoidea (2to0), Lanthanosuchoidea (2to1), Parareptilia except Mesosauridae (1to2), Varanopidae (1to2), Captorhinidae (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Tseajaia campi* (1to2), Caseidae (1to0), *Pantelosaurus saxonicus* (2to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to2), *Paleothyris acadiana* (1to2). DELTRAN: *Youngina capensis* (1to2). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (1to2)

98. Parietal, dorsoventrally narrow flange extending ventrally from the lateral margin of the parietal (ventrolateral flange): absent (0); present (1); inapplicable, lateral margin of parietal is not free (-)

From Laurin (1991 D.1), deBraga and Reisz (1995 c.6), deBraga and Rieppel (1997c.48), Müller (2004 c.157), Reisz *et al. (*2010 c.29).

This character can only be scored for taxa where the parietal possesses a free lateral margin (ch.95 state1) i.e. araeoscelidians, neodiapsids, *Orovenator mayorum* and the early synapsids *Edaphosaurus* and *Secodontosaurus*. Character state (1) is a synapomorphy of derived neodiapsids (Laurin 1991).

DELTRAN: Neodiapsida (0to1). ACCTRAN: Neoreptilia (0to1).

99. Supratemporal: present (0); absent (1)

From Laurin and Reisz (1995 c.18), Müller (2004: 21), Reisz *et al. (*2007 c.18), Benson (2012 c.88 state 3), Modesto *et al. (*2015 c.26).

In the current taxon list, the supratemporal is absent in the bolosaurid parareptiles *Belebey* and *Eudibamus* (Reisz *et al. 2*007). It is present in all other taxa.

Unambiguous: *Eudibamus cursoris* + *Belebey vegrandis* (0to1)

100. Supratemporal, size: broad element of skull table, mediolateral width is greater than 30% of width of posterior skull table from lateral margin of supratemporal to midline (0); slender, in parietal or parietal/squamosal trough, mediolateral width approximately 15% (1); inapplicable, supratemporal absent (-)

Modified from Reisz *et al. (*1998 c.22), Reisz and Dilkes (2003: 22), Maddin *et al.* 2006 c.28), Maddin *et al. (*2008 c.28), Reisz *et al. (*2009 c.37), Reisz *et al. (*2010 c.52) Benson (2012 c.88 in part), Modesto *et al. (*2018 c.31), Spindler *et al. (*2018 c.53).

Gephyrostegus (Klembara *et al.* 2014), *Seymouria* (Klembara *et al.* 2005) and diadectomorphs (Moss 1972, Berman *et al.* 2010) all possess a broad supratemporal (state 0) that occupies the posterolateral corner of the skull roof, with a minimum width of 30% of the posterior skull table from the lateral margin of the supratemporal to the midline. This condition is also present in caseasaurs such as *Eothyris, Oedaleops* and *Vaughnictis* and caseids (Reisz *et al.* 2009, Langston 1965, MCZ 2985, FMNH UC 656) and in parareptiles (deBraga and Reisz 1996, Reisz and Scott 2002, MacDougall *et al.* 2017). Maddin *et al. (*2008 c.28) and Reisz *et al. (*2009 c.37) added a third state to that of Maddin *et al. (*2006) to describe the posteroventral extent of the supratemporal in certain caseids (e.g. *Euromycter*, *Ennatosaurus*, C*otylorhynchus* and *Angelosaurus* (Maddin *et al.* 2008). In the present study, the increased posteroventral extent of the supratemporal of these taxa is described in the next character (ch.101). The supratemporal of captorhinids is a slender element (Fox and Bowman 1966, *Reiszorhinus* FMNH UC 183, *Romeria* texana MCZ 1480) and is scored as state (1), as are all araeoscelidians and neodiapsids (e.g. *Petrolacosaurus* Reisz 1981, *Youngina* Gow 1975 and *Prolacerta* Modesto and Sues 2004), ophiacodontids (e.g. *Varanosaurus* Berman *et al.*1995), sphenacodontians (e.g. *Secodontosaurus* Reisz *et al.*1992), edaphosaurids (e.g. *Edaphosaurus* Modesto 1995), varanodontines (e.g. *Aerosaurus* Langston and Reisz 1981) and mycterosaurines (e.g. *Mesenosaurus* Reisz and Berman 2001), with the exception of *Archaeovenator* (Reisz and Dilkes 2003). This character scores identically to a character describing the morphology of the posterolateral corner of skull (i.e. formed by parietal and small supratemporal or by supratemporal only) used in several analyses (e.g. Laurin and Reisz, 1995 c.26; Müller and Reisz, 2006 c.49; Laurin and Piñeiro, 2017 c.25) but is omitted from the current character list.

Parareptilia (1to0), *Archaeovenator hamiltonensis* (1to0). DELTRAN: Reptilia (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: Amniota (0to1), Caseasauria (1to0)

101. Supratemporal, posteroventral extent: approximately equal to or less than that of the tabular (0); greatly exceeds that of the tabular (1)

Modified from Maddin *et al. (*2009 c.28 state 2), Reisz *et al. (*2009 c.37 state 0)

Reisz and Fröbisch (2014) noted that in all synapsids, with the exception of caseids, the posteroventral extent of the supratemporal matches that of the tabular. In caseids (Reisz *et al.* 2009, Reisz and Fröbisch 2014) and in early parareptiles (Modesto 2006, Reisz and Fröbisch 2014, Gow 1972) the posteroventral extension of the supratemporal significantly exceeds that of the tabular.

Unambiguous: Parareptilia (0to1). DELTRAN: *Acleistorhinus pteroticus* (1to0), *Eocasea martini* (0to1), Caseidae (0to1). ACCTRAN: Lanthanosuchoidea (1to0), *Eothyris parkeyi* (1to0), Caseasauria (0to1)

102. Intertemporal: present (0), absent (1)

From Laurin and Reisz (1995 c.14), deBraga and Rieppel (1997 c.54), Klembara *et al. (*2014 c.23).

The intertemporal bone is present only in *Gephyrostegus* and *Seymouria* in the current taxon list (Klembara *et al.* 2005, 2014)

Unambiguous: Diadectomorpha + Amniota (0to1).

103. Tabular: present (0); absent (1)

From Laurin (1991 E.3), deBraga and Reisz (1996 c.15), deBraga and Rieppel (1997 c.55), Jalil (1997 c.2), Reisz and Dilkes (2003 c.46), Müller (2004 c.15), Reisz *et al. (*2010 c.53), Sumida *et al. (*2010 c.22), Benson (2012 c.86 state 3), Modesto *et al. (*2015 c.24), Pritchard *et al. (*2015 c.37).

The tabular is present in most of the taxa included in the present study. It is absent in captorhinids (Müller and Reisz 2005), *Claudiosaurus* (Carroll 1981), archosauromorphs (e.g. *Prolacerta* Gow 1975 and *Proterosuchus* Ezcurra 2016) and the parareptiles *Colobomycter pholeter* (MacDougall *et al.* 2017), *Macroleter poezicus* (Tsuji 2006), *Owenetta* (Reisz and Scott 2002) and *Procolophon* (Carroll and Lindsey 1985).

Unambiguous: Procolophonoidea (0to1), *Colobomycter pholeter* (0to1). DELTRAN: Archosauromorpha (0to1), *Claudiosaurus germaini* (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Euconcordia cunninghami* (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (1to0), Neodiapsida (0to1), *Thuringothyris mahlendorffae* (1to0), Captorhinidae (0to1)

104. Tabular, morphology: broad sub-rectangular sheet located dorsal to the fenestra (0); small and wedge-shaped, located dorsal to the post-temporal fenestra (1); long and narrow, displaced laterally, located dorsolateral to post-temporal fenestra (2); large L-shaped bone enclosing post-temporal fenestra dorsally and laterally (3); inapplicable tabular absent (-)

Modified from deBraga and Rieppel (1997 c.55), Sidor and Hopson (1998 c.54), Reisz and Dilkes (2003 c46), Maddin *et al. (*2006 c.29), Reisz *et al. (*2009 c.51), Berman *et al. (*1995 c.55), Benson (2012 c.86), Schoch and Sues (2015 c.55), Spindler *et al. (*2018 c.64/c.65).

The morphology of the tabular varies considerably among the terminal taxa of the present study, and presents challenges in describing character states that reflect potential homologies. In previous studies the descriptive emphasis has been focused on (i) the degree or absence of ventral expansion (deBraga and Rieppel 1997, Schoch and Sues 2015), (ii) mediolateral expansion (Reisz and Dilkes 2003, Maddin *et al. 2*006, Reisz *et al. 2*009, Spindler *et al. 2*018), (iii) description of the ventral expansion in respect to the post-temporal fenestra (Sidor and Hopson 1998, Berman *et al.*1995). In all of these examples the character is binary. Benson (2018) introduced a multistate character that encapsulates these morphological aspects, including the absence of the tabular (state 3). Herein we present a modified version of Benson (2012 c.86), with absence/presence removed to form a separate binary character (ch.103 above) and include a new state (state 1) that describes the tabular morphology in 'protorothyridids', *Petrolacosaurus*, *Youngina*, some parareptiles and early varanopids.

Unambiguous: Bolosauria (1to2), Reptilia (0to1), *Tseajaia campi* (0to2), Sphenacodontia + Edaphosauridae (0to3), *Araeoscelis* spp (1to2). DELTRAN: Mycterosaurinae + Varanodontinae (1to2), *Ennatosaurus tecton* (0to1). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to2), Caseidae (0to1)

105. Tabular, posteromedial process that contacts the dorsolateral corner of the supraoccipital: absent (0); present (1); inapplicable, tabular absent (-)

Modified from Benson (2012 c.87).

In *Heleosaurus* (Botha-Brink and Modesto 2009) and *Mesenosaurus* (Reisz and Berman 2001) a posteromedial semi-cylindrical hook-like process contacts the supraoccipital to provide the ventral margin of a small, dorsally positioned post-temporal fenestra.

DELTRAN: *Heleosaurus scholtzi* + *Mesenosaurus romeri* (0to1). ACCTRAN: Mycterosaurinae (0to1)

106. Supraoccipital, posterior surface: smooth or with a slight median ridge (0); with a prominent vertical median ridge (1)

From deBraga and Rieppel (1997 c.53), Muller and Tsuji (2007 c.60), Pritchard (2015 c.55), Ezcurra (2016 c.210)

Unambiguous: Ankyramorpha except Lanthanosuchoidea (0to1), Neoreptilia (1to0), Reptilia (0to1), Varanodontinae except *Aerosaurus wellesi* (1to0). DELTRAN: Sphenacodontidae (0to1), *Mesenosaurus romeri* (1to0). ACCTRAN: Sphenacodontia (0to1), *Heleosaurus scholtzi* + *Mesenosaurus romeri* (1to0)

107. Supraoccipital, lateral expansion providing dorsal margin of post temporal fenestra: absent (0); present (1)

Modified from Brinkman and Eberth (1983 c.15), Heaton and Reisz (1986 C), Laurin (1993 c.43), Benson (2012 c.92).

The presence of a lateral process of the supraoccipital (state 1) is variable among early synapsids, and absent in other early amniotes. In sphenacodontians the presence of state (1) is well documented (Romer and Price 1940, Brinkman and Eberth 1983, Reisz 1986), and with the elongate ventrolateral extension of the paroccipital process, this gives the supraoccipital/paroccipital plate a butterfly-like outline shape when seen in posterior view (Romer and Price 1940 plate 14). The lateral process of the supraoccipital forms the dorsal margin of the small post-temporal fenestra in these taxa. A similar morphology is present in *Edaphosaurus* (Modesto 1995). In varanodontines the presence of the lateral process (State 1) is quite distinct and forms the dorsal margin of the post-temporal fenestra (e.g. *Varanodon* FMNH UR 986, *Aerosaurus* Langston and Reisz 1981, *Varanops* Campione and Reisz 2010), although the paroccipital process is more dorsally orientated. In mycterosaurines, however, the lateral process is much reduced or absent (Reisz *et al.* 1998, Reisz and Berman 2001,). The lateral process is absent in *Ophiacodon, Eothyris* and *Casea* (Heaton and Reisz 1986), although Benson (2012) coded eothyridids as possessing the derived state. In *Eothyris* the supraoccipital forms the medial border of the post-temporal fenestra, and there is little evidence of a lateral extension, with the tabular providing the dorsal margin to the post-temporal fenestra (Reisz *et al. 2*009, MCZ 1161). Consequently, *Eothyris* is scored for state (0) herein, and *Oedaleops* as (?).

Unambiguous: Varanodontinae (0to1), Sphenacodontia + Edaphosauridae (0to1)

108. Postparietals: present (0); absent (1)

From Benton (1985 L.1), Carroll and Currie (1991 c.7b), Laurin and Reisz (1995 c.4), deBraga and Rieppel (1997 c.52).

The loss of the postparietals was considered a synapomorphy of derived archosaurs by Benton (1985), and of 'testudinomorpha' (i.e. procolophonoids + testudines) by Laurin and Reisz (1995). In the current taxon list, postparietals are absent (state 1) in *Claudiosaurus* (Carroll 1981), *Prolacerta* (Modesto and Sues 2004) and

Procolophon (Carroll and Lindsey 1985). *Proterosuchus* scores as state (0) (Ezcurra and Butler 2015).

Unambiguous: *Prolacerta broomi* (0to1), *Claudiosaurus germaini* (0to1), *Procolophon trigoniceps* (0to1)

109. Postparietals: unfused/paired (0); fused to form a midline element (1); inapplicable, postparietals absent (-)

Modified from Reisz *et al. (*1992 c.24), Laurin and Reisz (1995 c.4), Berman *et al. (*1995 c.30), deBraga and Rieppel (1997 c.52), Maddin *et al. (*2008 c.43), Benson (2012 c.91), Spindler *et al. (*2018 c.67).

Laurin and Reisz (1995) noted that the postparietals in all early amniotes, where present (i.e. ch.108 state (0) above), were paired elements. However, the postparietals are fused to form a single element (state 1) in several taxa (e.g. *Oedaleops*, Reisz *et al.* 2009; *Euromycter*, Sigogneau-Russell and Russell 1974 fig.6; *Archaeothyris*, Reisz 1972; *Ophiacodon and Dimetrodon*, Romer and Price 1940 plates 3 and 10; *Secodontosaurus*, Reisz *et al.*1992; *Proterosuchus*, Ezcurra 2016 and *Acleistorhinus*, deBraga and Reisz 1996, FMNH UR 1038). *Mycterosaurus* had been scored as lacking fusion between the postparietals by many studies. Spindler *et al. (*2018) recently differed from these, instead scoring the presence of fusion. Examination of the holotype FMNH UC 692 does appear to show a suture between the paired postparietals. However, Berman and Reisz (1982) attributed this feature in *Mycterosaurus* to a break along the midline due to crushing, and note its absence in a referred specimen. Consequently, *Mycterosaurus* is scored as possessing state (1) herein.

Unambiguous: *Ennatosaurus tecton* (1to0), *Varanosaurus acutirostris* (1to0). DELTRAN: *Proterosuchus* spp (0to1), *Deltavjatia rossicus* (0to1), *Nyctiphruretus acudens* (0to1), *Acleistorhinus pteroticus* (0to1), Synapsida (0to1), *Limnoscelis paludis* (0to1), *Eothyris parkeyi* + *Eocasea martini* (1to0), *Varanops brevirostris* (0to1), *Mycterosaurus longiceps* (0to1), ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), *Lanthanolania* + Archosauromorpha (0to1), Procolophonoidea (1to0), *Colobomycter pholeter* (1to0), Ankyramorpha (0to1), Reptilia (1to0), Amniota + Diadectomorpha (0to1), *Eothyris parkeyi* + *Eocasea martini* + *Vaughnictis smithae* (1to0), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (1to0)

110. Postparietals, incised by a median ascending process of the supraoccipital: absent, postparietals in contact along median height (0); present, postparietals separated from the midline ventrally by the supraoccipital (1); inapplicable, postparietals absent (-)

Modified from Dodick and Modesto (1995 c.14), Müller et *al. (*2006 c.14), Sumida *et al. (*2010 c.17), Modesto *et al. (*2018 c.33).

State (1) has been found as a synapomorphy of captorhinids (Heaton 1979, Modesto *et al.*1998, Modesto *et al. 2*018), and is also scored as present in all captorhinids herein, with the exception of *Reiszorhinus* (FMNH UC 183). It is also present in *Youngina* (Reisz *et al. 2*000).

Unambiguous: Captorhinidae (0to1) DELTRAN: *Youngina capensis* (0to1), *Reiszorhinus olsoni* (1to0). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), *Romeria* spp + *Reiszorhinus olsoni* (1to0)

111. Postparietals, size, transverse width of paired or single medial element: equal to or greater than the transverse width of one parietal at its widest point (0); less than the transverse width of one parietal (1); inapplicable, postparietals absent (-)

Modified from Laurin and Reisz (1995 c.4), MacDougall and Reisz (2014 c.9), Modesto *et al. (*2015 c.9).

The postparietals are transversely narrow in most derived parareptiles (Modesto *et al. 2*015), and independently in *Tseajaia* (Moss 1972) and *Eocasea* (Reisz and Fröbisch 2014).

Unambiguous: *Acleistorhinus pteroticus* (1to0), *Milleretta rubidgei* (1to0), Parareptilia (0to1), *Tseajaia campi* (0to1), *Eocasea martini* (0to1)

112. Postparietals, contribution to margin of post-temporal fenestra: absent (0); present (1); inapplicable, postparietals absent (-)

From Maddin *et al. (*2008 c.14).

The postparietals contribute to the dorsal margin of the post-temporal fenestra in the caseids *Euromycter* and *Ennatosaurus* (Maddin *et al. 2*008 c.14), and independently in *Procolophon* (Carroll and Lindsey 1985) and *Deltavjatia rossicus* (Tsuji 2013).

Unambiguous: *Procolophon trigoniceps* (0to1), *Euromycter rutena* + *Ennatosaurus tecton* (0to1). DELTRAN: *Deltavjatia rossicus* (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (0to1)

113. Opisthotic, paroccipital process, posterior extension: not visible in lateral view (0); visible in lateral view (1)

Modified from Benson (2012 c.96 in part), modified from Berman *et al. (*1995 c.54), deBraga and Reisz (1996 c.44), Maddin *et al. (*2006 c.33), Maddin *et al. (*2008 c.39), Reisz *et al. (*2009 c.53), Modesto *et al. (*2015 c.91).

Maddin *et al. (*2008) noted that the paroccipital process in caseasaurs projects posterior to the squamosal and is visible in lateral view (state 1), suggesting this feature was autapomorphic for caseasaurs. This feature can also be found in *Seymouria* (Laurin 1996), *Edaphosaurus* (Modesto *et al.*1995) and the parareptiles *Acleistorhinus* and *Procolophon* (FMNH UR 1038, Carroll and Lindsay 1985).

Unambiguous: *Seymouria* spp (0to1), Caseasauria (0to1). DELTRAN: *Owenetta kitchingorum* (0to1), *Acleistorhinus pteroticus* (0to1), *Edaphosaurus boanerges* (0to1). ACCTRAN: Owenettidae (0to1), Lanthanosuchoidea (0to1), Edaphosauridae (0to1)

114. Opisthotic, morphology and orientation of paroccipital process: robust and rod- like, extends laterally or ventrolaterally (0); slender and rod-like, extends posteroventrolaterally (1); dorsoventrally broad sheet with short lateral extension (2); dorsoventrally broad sheet, extends laterally or dorsolaterally (3)

Modified from Benson (2012 c.97), modified from Reisz (1986 table 3.E), Gauthier *et al.*1988 c.77/78/79), Laurin (1993 c.48/49), Laurin and Reisz (1995 c.56), Reisz *et al. (*1992 c.46/47/48), Laurin (1993 c.48/49/50), Berman *et al. (*1995 c.56), Reisz *et al. (*1998 c.26), Sidor and Hopson (1998 c.65), Fröbisch et *al. (*2011 c.35/36/37), Modesto *et al. (*2015 c.90).

Benson (2012) added state (3) to describe the condition in caseids, where the paroccipital process forms a broad rectangular sheet (Maddin *et al. 2*008). This score can also be applied to *Eothyris* (MCZ 1161). In sphenacodontids (e.g. *Dimetrodon*, Romer and Price 1940 plate 8, and *Secodontosaurus*, Reisz *et al.*1992) and in *Edaphosaurus* (Modesto 1995) the paroccipital process is slender distally and rod-like, extending ventrolaterally and somewhat posteriorly. In ophiacodontids (e.g. *Ophiacodon* Romer and Price 1940 plate 4 and *Varanosaurus* Berman *et al.*1995) the process is dorsoventrally broad with a short lateral extension (Reisz 1986).

Unambiguous: Caseasauria (1to3), *Araeoscelis* spp (0to2). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2), Sphenacodontidae (0to1), *Edaphosaurus boanerges* (0to1), Anthracodromeus hamiltonensis (0to2). ACCTRAN: 'protorothyridids' (0to2), Synapsida (0to1), *Haptodus garnettensis* (1to0), Ophiacodontidae (1to2)

115. Opisthotic, paroccipital process attachment: contacts skull laterally (0); ends freely (1)

Modified from Laurin (1991 A.4/E.6 with polarity reversal), Laurin and Reisz (1995 c.57 in part), Reisz and Dilkes (2003 c.26) Reisz *et al. (*2010 c.58), Modesto *et al. (*2015 c.92), Spindler *et al. (*2018 c.83 in part).

An osseous contact of the opisthotic with the dermatocranium is present in *Seymouria* (Laurin 1996) and *Limnoscelis* (Romer 1946, Berman *et al. 2*010), and this condition is considered plesiomorphic for the current taxon list. The derived condition, where the paroccipital process ends freely, is seen in *Varanosaurus* (Berman *et al.*1995), *Ennatosaurus* (Maddin *et al. 2*008), some captorhinids (Heaton 1979), 'protorothyridids' (Carroll 1969, Clark and Carroll 1973), *Petrolacosaurus* (Reisz 1981) and early parareptiles (Modesto *et al. 2*015).

Unambiguous: Neodiapsida except *Claudiosaurus* (1to0), Ankyramorpha (1to0), Reptilia (0to1), *Tseajaia campi* (0to1), *Ennatosaurus tecton* (0to1), *Varanosaurus acutirostris* (0to1), *Araeoscelis* spp (1to0). DELTRAN: Varanodontinae (1to0). ACCTRAN: Varanopidae (1to0)

116 Opisthotic, if paroccipital process contacts skull laterally contact is made with tabular: present (0); absent (1); inapplicable, process ends freely or tabular is absent (-)

Modified from Laurin and Reisz (1995 c.57 in part), Reisz *et al. (*1998 c.26), Maddin *et al. (*2006 c.33), Campione and Reisz (2010 c.33), Spindler *et al. (*2018 c.83).

Contact between the paroccipital process of the opisthotic and the tabular is present in *Limnoscelis* (Romer 1946, Fracasso 1987, Berman *et al. 2*010) and *Seymouria* (Laurin 1996), and some caseasaurs (e.g. *Eothyris* MCZ1161, *Casea* Olson 1968), sphenacodontids (Romer and Price 1940, Reisz *et al.*1992) and *Edaphosaurus* (Modesto 1995). Previous studies agree that the paroccipital process contacts the tabular in varanodontines (Reisz *et al.*1998, Maddin *et al. 2*006, Campione and Reisz 2010, Spindler *et al. 2*018), but disagree on *Mesenosaurus*, with only Spindler *et al. (*2018) scoring as present. We concur that contact between the tabular and paroccipital process was probably present in *Varanops* and *Varanodon* (FMNH UR 986, FMNH UC 644), but find no evidence for its presence in mycterosaurines, which we score as (?) until further data is available.

Unambiguous: Neoreptilia (0to1).

117. Prootic, lateral surface: continuous and slightly convex, lacking crista prootica (0); crista prootica present (1)

From Jalil (1997 c.69), Dilkes (1998 c.47), Ezcurra *et al. (*2014 c.153), Pritchard *et al.*

(2015 c.73).

The crista prootica is a prominent ridge of bone that extends anteroposteriorly along the lateral surface of the prootic in archosaurs and derived lepidosaurs (Evans 1986), often extending ventrolaterally to overhang the foramina for the facial nerves (Rieppel and Zaher 2000). It is absent in *Youngina* (Evans 1987), but present in *Prolacerta* and *Proterosuchus* (Evans 1986, Ezcurra *et al. 2*014). DELTRAN: Archosauromorpha (0to1) ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1)

118. Prootic, anterior inferior process: absent (0); present (1)

From Dilkes (1998 c.48), Ezcurra *et al. (*2014 c.154), Pritchard *et al. (*2015 c.74).

The anterior inferior process of the prootic articulates with the clinoid process of the parabasisphenoid and supports the pila antotica. It is present in *Prolacerta* and *Proterosuchus* (Evans 1986, Ezcurra *et al. 2*014). Evans (1987) noted its absence in *Youngina*, although this was subsequently reported as being present based on microCT analysis (Gardner *et al. 2*010).

DELTRAN: Neodiapsida except *Claudiosaurus* (0to1). ACCTRAN: Neoreptilia (0to1)

119. Exoccipital, lateral wing: tall and narrow (0); broad, extending ventral to paroccipital process (1)

From Laurin and Reisz (1995 c64), Tsuji (2006 c.74), Reisz *et al. (*2009 c.52), Benson (2012 c.95), Modesto *et al. (*2015 c.102), Spindler *et al. (*2018 c.84).

In some early amniotes the ventral region of the exoccipital extends laterally to form a flange of bone that extends ventral to or contacts the ventral process of the opisthotic. This condition (state 1) is present in caseasaurs (Reisz *et al. 2*009, Olson 1968), some 'protorothyridids' (Carroll 1969), *Youngina* (Evans 1987), *Prolacerta* (Evans 1986) and *Macroleter* (the 'lateral flange' of Modesto *et al. 2*015).

Unambiguous: Neodiapsida except *Claudiosaurus* (0to1), Pareiasauria + Nycteroleteridae (0to1), *Archaeothyris florensis* (0to1), Caseasauria (0to1), *Paleothyris acadiana* + *Protorothyris archeri* (0to1)

120.Exoccipitals enclose the complete ventral margin of the foramen magnum: absent, margin provided by the basioccipital (0) present (1)

Modified from deBraga and Rieppel (1997 c.62 with polarity reversal), Nesbitt (2011 c.115), Schoch and Sues (2015 c.52), Pritchard *et al. (*2015 c.61).

In diadectomorphs (Romer 1946, Moss 1972), caseasaurs (Olson 1968, Reisz *et al. 2*009), sphenacodontians (Romer and Price 1940, Laurin 1993), *Edaphosaurus*

(Modesto 1995), *Mesenosaurus* (Reisz and Berman 2001), *Aerosaurus* (Langston and Reisz 1981), 'protorothyridids' and captorhinids (Clark and Carroll 1973), *Petrolacosaurus* (Reisz 1981), *Prolacerta* (Evans 1986) and some parareptiles (e.g. *Milleretta* Gow 1972, *Acleistorhinus* deBraga and Reisz 1996) the basioccipital contributes to the ventral margin to the foramen magnum (state 0). In the current taxon list, the contact of the exoccipitals ventral to the foramen magnum, excluding the basioccipital from this margin (state 1), is present in derived ophiacodontids (Romer and Price 1940, Berman *et al.*1995,), *Varanops* (Campione and Reisz 2010) and some parareptiles (e.g. *Macroleter*, Tsuji 2006; *Belebey*, Reisz *et al. 2*007).

DELTRAN: *Belebey vegrandis* (0to1), *Owenetta kitchingorum* (0to1), Pareiasauria + Nycteroleteridae (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), *Varanops brevirostris* (0to1). ACCTRAN: *Procolophon trigoniceps* (1to0), Ankyramorpha except Lanthanosuchoidea (0to1), Bolosauria (0to1), Ophiacodontidae (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1)

121. Basioccipital, occipital condyle orientation: posteriorly directed (0); posteroventrally directed (1)

From Maddin *et al. (*2008 c.42), Benson (2012 c.98).

A posteroventrally directed occipital condyle (state 1) is present only in caseids (Maddin *et al. 2*008, Olson 1968) and *Edaphosaurus* (MCZ 4309) in the current taxon list. This may be associated with convergent adaptation to herbivory.

Unambiguous: Caseidae (0to1). DELTRAN: *Edaphosaurus boanerges* (0to1). ACCTRAN: Edaphosauridae (0to1).

122. Basal articulation, position: approximately level with posterior rim of the transverse flange of pterygoid (0); anterior to rim of the transverse flange (1); posterior to the rim transverse flange (2)

Modified from Reisz *et al. (*1992 c.42), Berman *et al. (*1995 c.50), Sidor and Hopson (1998 c.73), Maddin *et al. (*2008 c.34), Fröbisch et *al. (*2011 c.104), Benson (2012 c.101).

Most early amniotes have a basal articulation of the pterygoid that is level with the posterior rim of the transverse flange (state 0). Caseids (*Casea broilii* FMNH UR 1011, Maddin *et al. 2*008) are autapomorphic for the basal articulation being situated anterior to the rim (state 1). A posteriorly located basal articulation (state 2) is present in diadectomorphs (Moss 1972, Berman *et al. 2*010), sphenacodontians (Romer and Price 1940, Reisz *et al.*1992, *Haptodus garnettensis* ROM 43606), captorhinids (*C. laticeps* OMNH 15101, *R. texana* MCZ 1480) and ankyramorph parareptiles (MacDougall *et al. 2*017, Tsuji 2006, Cisneros 2008).

Unambiguous: Captorhinidae except *Euconcordia* and *Thuringothyris* (0to2), Diadectomorpha (0to2), Caseidae (0to1), Sphenacodontia (0to2). DELTRAN: Ankyramorpha (0to2), *Mesosaurus tenuidens* (0to2). ACCTRAN: Bolosauria (2to0), Parareptilia (0to2)

123. Basal articulation, orientation of basipterygoid process: anteroventrolaterally directed (0); laterally directed (1); distinctly ventrally or posteroventrally directed (2)

Modified from Brinkman and Eberth (1983 c.3), Reisz *et al. (*1992 c43), Berman *et al. (*1995 c.51), Dilkes (1998 c.43), Reisz and Dilkes (2003 c.20), Müller (2004 c.96), Maddin *et al. (*2006 c.39), Benson (2012 c.102), Pritchard *et al. (*2015 c.70), Spindler *et al. (*2018 c.74/75)

Characters concerning the basipterygoid processes of the parabasisphenoid have tended to focus on two aspects of its morphology, (i) the orientation of the process and (ii) the direction of the articulating facets. The paroccipital process is directed anteroventrolaterally (state 0) in most terminal taxa herein. Caseasaurs (*Eothyris* MCZ 1161, *Casea broilii* FMNH UR 1011), early varanopids and mycterosaurines (*Archaeovenator* KUVP 12483, Vaughn 1958, Reisz and Berman 2001, Spindler *et al. 2*018), varanodontines (Langston and Reisz 1981) and *Prolacerta* (BP/1/5066) share the condition of a laterally directed process (state 1). Derived ophiacodontids (*Ophiacodon retroversus* MCZ 4820, *Varanosaurus* FMNH PR 1670) have a strongly ventrally or posteroventrally directed basipterygoid process (state 2).

Unambiguous: Varanopidae (0to1), Caseasauria (0to1), *Orovenator mayorum* (1to0). DELTRAN: *Prolacerta broomi* (0to1), *Mesosaurus tenuidens* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2). ACCTRAN: Archosauromorpha (0to1), Mesosauridae (0to1), Ophiacodontidae (0to2)

124. Parabasisphenoid, dentition posterior to level of transverse flange: absent (0); present (1)

Modified from Laurin and Reisz (1995 c.53), Reisz and Dilkes (2003 c.45), Reisz *et al. (*2009 c.54), Reisz *et al. (*2010 c.50), Benson (2012 c.109 state 1).

Teeth are absent from the ventral surface of the parasphenoidal plate posterior to the transverse flange of the pterygoid (state 0) in *Gephyrostegus* (Klembara *et al. 2*014), *Seymouria* (White 1939, Laurin 1996) and diadectomorphs (Moss 1972, Berman *et al. 2*010) and most early amniotes. Teeth are present (state 1) in most varanopids, although they are absent in *Archaeovenator* (Reisz and Dilkes 2003, Spindler *et al. 2*018). They are also present in 'protorothyridids' (Carroll 1964,1969), *Orovenator* (Reisz *et al. 2*011), *Petrolacosaurus* (Reisz 1981), the early captorhinid *Euconcordia* (Müller and Reisz 2005) and some parareptiles

(MacDougall *et al. 2*017, deBraga and Reisz 1996, Gow 1972).

Unambiguous: *Archaeovenator hamiltonensis* (1to0). DELTRAN: Lanthanosuchoidea (0to1), *Milleretta rubidgei* (0to1), Varanopidae (0to1), *Euconcordia cunninghami* (0to1), *Euromycter rutena* (0to1), *Hylonomus lyelli* (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Ankyramorpha except Lanthanosuchoidea (1to0), Parareptilia except Mesosauridae and Bolosauria (0to1), Neoreptilia (1to0), Captorhinidae except *Euconcordia* (1to0), Reptilia (0to1), *Euromycter rutena* + *Ennatosaurus tecton* (0to1), *Araeoscelis* spp (1to0)

125. Parabasisphenoid, dentition on ventral surface of cultriform process: absent (0); present (1)

Modified from Laurin and Reisz (1995 c.53), Maddin *et al. (*2008 c.30), Reisz and Fröbisch (2014 c.30).

The presence of teeth on the ventral surface of the cultriform process (state 1) is a derived condition in early amniotes and follows a similar distribution pattern for the preceding character (ch. 124), except for its additional presence in caseasaurs (Maddin *et al. 2*008, Brocklehurst *et al. 2*016), *Lanthanolania* (Modesto and Reisz 2002) and *Captorhinus aguti* (Fox and Bowman 1966).

Unambiguous: *Lanthanolania ivakhnenkoi* (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1), Lanthanosuchoidea (0to1), *Milleretta rubidgei* (0to1), 'protorothyridids' (0to1), *Euconcordia cunninghami* (0to1), Caseasauria (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Ankyramorpha except Lanthanosuchoidea (1to0), Parareptilia except Mesosauridae and Bolosauria (0to1), Neoreptilia (1to0), Captorhinidae except *Euconcordia* (1to0), Amniota (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to0), *Araeoscelis* spp (1to0)

126. Parabasisphenoid, entry foramen for the internal carotid arteries: on the ventral surface of the parabasisphenoid, medial to the basipterygoid process (0); within the lateral wall of braincase, dorsal to the basipterygoid process (1) within ventral surface of the parabasisphenoid.

Modified from Gower and Sennikov (1996 c.1), Dilkes (1998 c.45), Nesbitt (2011 c.95), Pritchard *et al. (*2015 c.67), Ezcurra (2016 c.240)

The position of the entry foramina for the internal carotid artery has long been used as a character in phylogenetic studies of archosaurs (Parrish 1993 c.7, Gower and Sennikov 1996 c.1), and also varies among early amniotes. State (1) describes the presence of entry foramina on the lateral surface of the parabasisphenoid, anterior to the suture with the prootic and dorsal to the basipterygoid process. This condition is present in some parareptiles, e.g. *Procolophon* (Carroll and Lindsey 1985) and *Milleretta* (Gow 1972) as well as in squamates, crown-group turtles and birds (Müller et *al. 2*011). State (0), describing entry foramina located on the ventral surface of the parabasisphenoid, is present in most early amniotes (Brinkman and Eberth 1983, Müller et *al. 2*011, Ford and Benson 2018). Langston and Reisz (1981) suggested that the position of the entry foramen in the varanodontine *Aerosaurus* is located on the lateral surface of the parabasisphenoid, but we consider this interpretation uncertain since (i) a foramen is also observed at the base of the basipterygoid process in this taxon, in a position similar to that of *Mycterosaurus* (Vaughn 1958, Reisz *et al.*1997) and *Orovenator* (Ford and Benson 2018), (ii) the pathway of the internal carotid suggested by Langston and Reisz is associated with the division of this artery into the cerebral and palatal branches taking place within the bone of the basisphenoid, a condition only found in parareptiles, squamates, crown-group turtles and birds (Müller et *al. 2*011), (iii) in *Aerosaurus*, the pathway of the cerebral branch of the internal carotid to the exit foramina, located in the pituitary fossa on the dorsal surface of the basisphenoid, remains hypothetical. We have therefore scored *Aerosaurus* as (?) herein.

Unambiguous: Parareptilia except Mesosauridae and Bolosauria (0to1)

127. Parabasisphenoid, lateral parasphenoidal crests: present as prominent lateral extensions framing the ventromedial floor of the vidian sulcus, and obscuring the entry foramen of the internal carotid artery from ventral view (0); absent, such that there is no ventral floor to the passage of the internal carotid artery, and the entry foramina of the internal carotid are visible in ventral view (1); inapplicable, entry foramen is located on the lateral surface of the parabasisphenoid (-)

Modified from Pritchard *et al. (*2015 c.66), Ezcurra (2016 c.246).

In *Seymouria* (Shishkin 1968 fig.5), *Casea broilii* (Brinkman and Eberth 1983, FMNH UR 1011), some captorhinids (Fox and Bowman 1966, Müller and Reisz 2005), neodiapsids (Evans 1986, 1987, Ford and Benson 2018), varanodontines (cf. *Varanops*, Maddin *et al. 2*006) and *Mycterosaurus* (Vaughn 1958, Reisz *et al.*1997) a lateral expansion of the parasphenoidal plate provides a floor for the passageway (vidian sulcus) of the internal carotid artery, all but enclosing the entry foramen between the basipterygoid process and the parasphenoidal crest (state 0). In sphenacodontians, ophiacodontids and *Edaphosaurus*, the entry foramina for the cerebral branch of the internal carotid artery is located on the ventral surface of parabasisphenoid close to the median line, between the basipterygoid processes (Brinkman and Eberth 1983 fig.7). A similar condition can be seen in the parareptile *Belebey* (Reisz *et al. 2*007 fig.8).

Unambiguous: Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1).

DELTRAN: Parareptilia except Mesosauridae (0to1). ACCTRAN: Parareptilia (0to1)

128. Parabasisphenoid, body shape: transversely broad, width greater than length from basipterygoid processes to posterior end (0); transversely narrow, length greater than width (1)

Modified from Reisz *et al. (*1992 c.44), Laurin (1993 c.41), Berman *et al. (*1995 c.52), Maddin *et al. (*2008 c.31), Benson (2012 c.104).

The body of the parabasisphenoid posterior to the basipterygoid processes is long and narrow (state 1) in *Ophiacodon and* sphenacodontids (Romer and Price 1940, *Secodontosaurus* MCZ 2028) and the parareptile *Deltavjatia rossicus* (Tsuji 2013). In other terminal taxa, the parabasisphenoid becomes mediolaterally broader posteriorly.

Unambiguous: *Ophiacodon* spp (0to1). DELTRAN: *Deltavjatia rossicus* (0to1), Sphenacodontidae (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (0to1), Sphenacodontia except *Haptodus* (0to1)

129. Parabasisphenoid, outline of lateral margin, anterior 'shoulder' level with the basal articulation in ventral view: absent (0); present (1)

From Maddin *et al. (*2006 c.36) , Campione and Reisz (2010 c.36), Benson (2012 c.105) Spindler *et al. (*2018 c.78).

This character describes the abrupt lateral expansion of the transverse width of the anterior region of the parabasisphenoid instead of a gradual increase in transverse width. State (1) is only seen in *Mesenosaurus* (Reisz and Berman 2001) and *Aerosaurus* (Langston and Reisz 1981). The scoring of the derived state for *Pyozia*, *Heleosaurus* and *Mycterosaurus* (Spindler *et al.* 2018) is rejected herein, since the parabasisphenoid is either too poorly preserved to be scored (e.g. *Pyozia*, Anderson and Reisz 2004) or the anterior 'shoulder' is absent (e.g. *Heleosaurus*, Reisz and Modesto 2007 fig.3 and *Mycterosaurus*, Vaughn 1958 fig.1).

Unambiguous: *Aerosaurus wellesi* (0to1), *Mesenosaurus romeri* (0to1)

130. Parabasisphenoid, ventral plate, medial excavation: depression or concavity between the cristae ventrolaterales (0); deep median groove present (1); absent, ventral surface flat (2)

Modified from Benson (2012 c.106) modified from Laurin (1993 c.41), Laurin and Reisz (1995 c.50), Berman (1995 c.52), Maddin *et al. (*2006 c.37), Tsuji (2006 c.60), Nesbitt (2011 c.100), MacDougall and Reisz (2014 c.81/82), Modesto *et al. (*2015 c.82/83), Modesto *et al. (*2018 c.47)

The region medial to the cristae ventrolaterales of the parabasisphenoid has a moderate concavity (state 0), possibly for the insertion of cervical musculature, in diadectomorphs (Moss 1972, Fracasso 1987), *Seymouria* (White 1939) and many early amniotes. A much deeper median groove (state 1) is present in ophiacodontids (Berman *et al.*1995) ,sphenacodontians (Reisz *et al.*1992) and derived captorhinids. In archosauromorphs the surface is relatively flat (state 2) (Nesbitt 2011), although Modesto and Sues (2004:344) note a 'deep parabolic depression' in *Prolacerta* (BP/1/5006), which we score as [1,2] for uncertainty.

Unambiguous: *Nyctiphruretus* + Procolophonoidea (0to2), *Milleretta rubidgei* (0to2). DELTRAN: Archosauromorpha (0to2), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontia (0to1). ACCTRAN: Neodiapsida except *Claudiosaurus* (0to2), Captorhinidae except *Euconcordia* (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

131. Parabasisphenoid, ventral plate, median longitudinal septum or ridge: absent (0); present (1)

From Benson (2012 c.108), Spindler *et al. (*2018 c.79)

A raised ridge is present on the midline of the ventral surface of the parabasisphenoid (state 1) in diadectomorphs (Moss 1972, Berman *et al.* fig.10a), mycterosaurines (Vaughn 1958, Anderson and Reisz 2004 fig.1), *Varanosaurus* (FMNH PR 1670) and *Mesosaurus* (Modesto 2006), dividing the concavity between the cristae ventrolaterales into paired fossae. Modesto (2006) noted that the median ridge was absent in most Paleozoic amniotes, but present in the holotype of *Paleothyris acadiana* based on illustrations in Carroll (1996 fig.1). However, close examination of this specimen (MCZ 3481) shows the medial ridge to be absent in this taxon.

Unambiguous: Mycterosaurinae (0to1), Diadectomorpha (0to1), *Varanosaurus acutirostris* (0to1). DELTRAN: *Mesosaurus tenuidens* (0to1). ACCTRAN: Mesosauridae (0to1)

132. Vomer, teeth or shagreen: present (0); absent (1)

From Gauthier *et al. (*1988 c.120), Reisz *et al. (*1992 c.64), Laurin (1993 c.77), Berman *et al. (*1995 c.71), Sidor and Hopson (1998 c.40), Fröbisch et *al. (*2011 c.61), Benson (2012 c.112), Modesto *et al. (*2018 c.37)

Most early amniotes share state (0), the presence of teeth or shagreen of denticles on the vomer. However, they are independently absent in some groups, including sphenacodontids (Romer and Price 1940, Fröbisch et *al. 2*011 c.61), captorhinids (Fox and Bowman 1966, Heaton 1979, Modesto *et al. 2*018) and bolosaurid parareptiles (Berman *et al. 2*000, Reisz *et al. 2*007). Vomerine teeth are also absent in *Limnoscelis* (Romer 1946, Berman *et al. 2*010).

Unambiguous: *Limnoscelis paludis* (0to1), Sphenacodontidae (0to1), *Eudibamus* + *Belebey* (0to1). DELTRAN: *Captorhinus* + *Protocaptorhinus* + *Romeria* (0to1), *Thuringothyris mahlendorffae* (0to1). ACCTRAN: *Euconcordia cunninghami* (1to0), Captorhinidae (0to1).

Unambiguous: Captorhinidae except *Euconcordia* (0to1), *Limnoscelis paludis* (0to1). DELTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), Sphenacodontidae (0to1). ACCTRAN: Bolosauria (0to1), Sphenacodontidae + *Cutleria wilmarthi* (0to1)

133. Vomer, fangs: present (0); absent (1)

From Klembara *et al. (*2014 c.68)

In the current taxon list only *Gephyrostegus* and *Seymouria* (Klembara *et al. 2*005, 2014) possess vomerine fangs. This is also a feature of temnospondyl anamniotes (Laurin and Reisz 1997).

Unambiguous: Diadectomorpha + Amniota (0to1).

134. Vomer, asymmetric bifurcated anterior processes: present, vomer terminates anteriorly in short lateral and elongate medial projections (0); absent (1)

NEW

Some early amniotes possess a distinctive bifurcation of the anterior tip of the vomer, separated by the vomerine process of the premaxilla, with a short lateral process and long medial process that meets its partner at the midline of the palate. This feature is present in early varanopids and mycterosaurines (e.g. *Archaeovenator*, Reisz and Dilkes 2003 and *Mesenosaurus*, Reisz and Berman 2001), the 'protorothyridid' *Paleothyris*(MCZ 3481, Carroll 1969 fig.1b), araeoscelidians (e.g. *Petrolacosaurus*, KUVP 8351, Reisz 1981), *Orovenator (*Ford and Benson 2018) and the early parareptile *Erpetonyx* (ROM 55402, Modesto *et al. 2*015 fig.2a). In most early synapsids in which this region can be observed, the premaxillae meets the vomers with medially directed processes (e.g. *Ennatosaurus* and *Dimetrodon limbatus*; Olson 1968 fig.3b, Romer and Price plate 13), laterally directed processes forming the anterior margin to the internal nares (e.g. *Varanosaurus*; Berman *et al.*1995), or in a short butt joint (e.g. *Secodontosaurus*; Reisz *et al.*1992). The presence of this character state may be plesiomorphic, however, as *Limnoscelis* possesses a bifurcated anterior tip of the vomer, which is slightly differentiated in length (Berman *et al.* 2010).

DELTRAN: Varanopidae except *Ascendonanus* (1to0), Erpetonyx arsenaultorum (1to0), *Limnoscelis paludis* (1to0), *Paleothyris acadiana* (1to0), *Petrolacosaurus kansensis* (1to0), ACCTRAN: Bolosauria (1to0), Neoreptilia (0to1), Reptilia except Captorhinidae (1to0), Diadectomorpha (1to0), *Protorothyris archeri* (0to1)

135. Vomer, medial contact with pterygoid: absent (0); present (1); inapplicable pterygoid does not contact the vomer (-)

NEW

An incision of the pterygoid between the posteromedial margins of the vomers is absent in several early amniotes (state 0), and the vomers remain in contact at the midline throughout their anteroposterior length (e.g. *Tseajaia*, Moss 1972; *Gephyrostegus*, Carroll 1970; *Casea*, FMNH UR 1011; *Edaphosaurus*, Modesto 1995; *Haptodus*, Laurin 1993 and *Ophiacodon,* Romer and Price 1940). An extensive incision (state 1) is present in early varanopids and mycterosaurines (Reisz and Dilkes 2003, Reisz and Berman 2001, Ford and Benson 2018), 'protorothyridids' (Clark and Carroll 1973), captorhinids (Fox and Bowman 1966), *Petrolacosaurus* (Reisz 1981), neodiapsids (Gow 1975) and most parareptiles (Tsuji 2006, MacDougall *et al.* 2017). A smaller medial incision is found in *Dimetrodon* (Romer and Price 1940), which is scored herein as state (1). In the parareptile *Belebey* there is small fenestra preventing contact between the pterygoid and the vomer, which possibly functioned as a secondary palate (Reisz *et al.* 2007), and is therefore scored as state (0).

DELTRAN: *Belebey vegrandis* (1to0), *Deltavjatia rossicus* (1to0), Reptilia (0to1), *Seymouria* spp (0to1), *Limnoscelis paludis* (0to1), *Dimetrodon* spp (0to1). ACCTRAN: *Emeroleter levis* + *Deltavjatia rossicus* (1to0), Bolosauria (1to0), Synapsida (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Tseajaia campi* (1to0), Sphenacodontia except *Haptodus* (0to1)

136. Vomer, if medial contact with pterygoid is present it is: extensive (≥50% median border of vomer) (0); short (≥33% median border of vomer) (1); inapplicable, medial contact absent (-)

From Modesto *et al. (*2007 c.19), Sumida *et al. (*2010 c.26), Modesto *et al. (*2014 c.38), Modesto *et al. (*2018 c.38)

This character distinguishes between early (with extensive medial contact) and derived (short medial contact) captorhinids in the above referenced studies. Extensive medial contact is also present in *Pyozia* (Anderson and Reisz 2004), *Seymouria* (Klembara *et al. 2*005), *Protorothyris* (Clark and Carroll 1973) and *Romeria texana* (MCZ 1480).

Unambiguous: Amniota + Diadectomorpha (0to1). DELTRAN: *Romeria* spp (1to0), *Protorothyris archeri* (1to0). ACCTRAN: 'protorothyridids' (1to0), *Romeria* spp + *Reiszorhinus olsoni* (1to0)

137. Palatine, teeth or shagreen: present (0); absent (1)

From Gauthier *et al. (*1988 c.121), Laurin (1993 c.78), Dilkes (1998 c.67), Sidor and Hopson (1998 c. 36), Müller (2004 c.99), Benson (2012 c.114), Spindler *et al. (*2018 c.68), Modesto *et al. (*2018 c.39)

Palatine dentition is present in *Seymouria* and *Gephyrostegus* (Klembara *et al. 2*005, 2014), and also in most early amniotes. Klembara and Ruta (2005) scored palatine dentition as absent in *Limnoscelis*. However, Berman *et al. (*2010) noted a narrow field of small denticles on the palatine, and this taxon has been scored accordingly as state (0). Palatine teeth are absent in *Tseajaia* (Moss 1972), derived ophiacodontids (Romer and Price 1940, Berman *et al.*1995) and in bolosaurian parareptiles (Berman *et al. 2*000, Reisz *et al. 2*007).

Unambiguous: *Labidosaurikos meachami* (0to1), *Tseajaia campi* (0to1). DELTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: Bolosauria (0to1), Ophiacodontidae (0to1)

138. Palatine, fangs: present (0), absent (1)

From Klembara *et al. (*2014 c.62)

Unambiguous: Diadectomorpha + Amniota (0to1).

139. Palatine, incision of anterior surface to accommodate internal naris (choana): shallow to moderate anterior incision (0); deep anterior incision (1); palatine is not incised, or only a small notch is present (2)

NEW

In early and mycterosaurine varanopids (e.g. *Archaeovenator*, Reisz and Dilkes 2003; *Heleosaurus*, Reisz and Modesto 2007; *Mesenosaurus*, Reisz and Berman 2001), *Orovenator (*Ford and Benson 2018) and *Proterosuchus* (Wellman 1998) the anterior surface of the palatine is deeply incised, and forms the posterolateral and posteromedial margin of the internal naris. The incision of the palatine by the external naris is absent in most early synapsids (e.g. *Dimetrodon limbatus*, *Ophiacodon uniformis*, Reisz 1986; *Haptodus*, Laurin 1993; *Casea*, FMNH UR 1011, Olson 1968 and *Edaphosaurus* Modesto 1995). It is also absent in captorhinids (Fox and Bowman 1966, *Romeria texana* MCZ 1480) and the parareptile *Belebey* (Reisz *et al. 2*007). In the current taxon list, all 'protorothyridids', most neodiapsids and parareptiles possess a moderate or shallow incision to the anterior palatine.

Unambiguous: *Proterosuchus* spp (0to1), Synapsida (0to2), *Seymouria* spp (0to1), *Tseajaia campi* (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1), *Belebey vegrandis* (0to2), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to2). ACCTRAN: Bolosauria (0to2), Varanopidae (0to1), Captorhinidae except *Euconcordia* (0to2)

140. Pterygoid, transverse flange: large, approaches cheek, a noticeable lateral projection (0); small, does not approach cheek (1)

From Modesto *et al. (*2015 c.68), modified from Lee (1997 c.19), Tsuji (2006 c.50), Tsuji *et al. (*2012 c.47), MacDougall and Reisz (2014 c.68)

State (1) of this character describes a synapomorphy of bolosaurian parareptiles *Eudibamus* and *Belebey*. It is also present in the pareiasaur *Deltavjatia rossicus*. All other terminal taxa, where the pterygoid can be observed, as scored as state (0) including stem-group amniotes (e.g. *Gephyrostegus*, *Seymouria*, *Tseajaia* and *Limnoscelis*), where the transverse flange is also present.

Unambiguous: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), *Deltavjatia rossicus* (0to1)

141. Pterygoid, teeth on transverse flange: present (0); absent (1)

From Gauthier *et al. (*1988 c.123), Laurin and Reisz (1995 c.46), deBraga and Rieppel (1997 c.78), Reisz *et al. (*2007 c.46), Modesto *et al. (*2015 c.70), Laurin and Piñeiro (2017 c.46)

The presence of teeth on the transverse flange is a symplesiomorphy that is present in almost all early amniotes. Exceptionally, bolosaurian and procolophonoid parareptiles lack any dentition on the transverse process of the pterygoid (Reisz *et al. 2*007, Berman *et al. 2*000, Carroll and Lindsey 1985, Modesto *et al. 2*015 - although in this latter study there is an error in the caption of fig.2 in respect to the unambiguous synapomorphies of Bolosauria, since character 70, state 1 = 'absent' rather than 'present')

Unambiguous: Procolophonoidea (0to1), Bolosauria (0to1)

142. Pterygoid, arrangement of teeth on transverse flange: a field or shagreen of teeth covering the ventral surface of the flange (0); additional teeth anterior to a single row of large teeth on ventral rim of flange (1); single row of teeth on ventral rim of flange (2); inapplicable, teeth absent from

transverse flange (-)

Modified from Laurin (1991 E.5), Reisz *et al. (*1998 c.30), Reisz and Dilkes (2003 c.30), Müller (2004 c.163), Maddin *et al. (*2006 c.35), Reisz *et al. (*2009 c.56), Reisz *et al. (*2010: 49), Benson (2012 c.123), Pritchard *et al. (*2015 c.51), Spindler *et al. (*2018 c.69), Modesto *et al. (*2018 c.42)

State (0) describes a field of teeth covering most of the ventral surface of the transverse process, and is present in *Gephyrostegus*, *Seymouria* and *Tseajaia*, captorhinids (e.g. C. *laticeps*, OMNH 15101) and *Euconcordia* (Reisz *et al. 2*016), the early 'protorothyridid' *Hylonomus* (Carroll 1964), some caseasaurs (e.g. *Casea*, FMNH UC 1011, Olson 1968; *Vaughnictis*, Brocklehurst *et al. 2*016) and edaphosaurids (e.g. *Ianthasaurus*, ROM 59933; *Edaphosaurus*, Modesto 1995), in which it may represent a secondary reacquisition. A single row of teeth is found in ophiacodontids (e.g. *Ophiacodon,* Romer and Price 1940; *Varanosaurus*, Berman *et al.*1995)), sphenacodontids (e.g. *Dimetrodon*, Romer and Price 1940; *Secodontosaurus*, Reisz *et al.*1992), varanodontines (e.g. *Aerosaurus*, Langston and Reisz 1981), several early and mycterosaurine varanopids (e.g. *Ascendonanus*, Spindler *et al. 2*018; *Elliotsmithia*, Reisz *et al.*1998), neodiapsids (e.g. *Youngina*, Gow 1975; *Prolacerta*, Modesto and Sues 2004) and the parareptile *Macroleter* (Tsuji 2006).

Unambiguous: Apsisaurus witteri (2to1), Neodiapsida except *Claudiosaurus* (0to2), Pareiasauria + Nycteroleteridae (1to2), Varanopidae (0to2), Araeoscelidia (0to1), *Labidosaurikos meachami* (0to2), *Limnoscelis paludis* (0to1), *Ennatosaurus tecton* (0to1), *Haptodus garnettensis* (2to1), *Protorothyris archeri* (1to2), *Orovenator mayorum* (2to1), *Varanops brevirostris* (2to1), *Mesenosaurus romeri* (2to1), *Mycterosaurus longiceps* (2to1). DELTRAN: Parareptilia except Mesosauridae and Bolosauria (0to1), *Eothyris parkeyi* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2), Sphenacodontidae (0to2), *Paleothyris acadiana* (0to1), ACCTRAN: Parareptilia except Mesosauridae (0to1), *Eothyris parkeyi* + *Eocasea martini* (0to1), Edaphosauridae (2to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to2), 'protorothyridids' except *Hylonomus* (0to1)

143. Pterygoid, orientation of the transverse flange: directed predominately laterally or posterolaterally (0); directed anterolaterally (1); directed anteriorly (2)

Modified from Laurin and Reisz (1995 c.45), deBraga and Rieppel (1997 c.77), Müller (2004 c.140), Maddin *et al. (*2008 c.37), Benson (2012 c.118), Modesto *et al. (*2015 c.69), Pritchard *et al. (*2015 c.53)

Most terminal taxa possess state (0), a laterally or posterolaterally directed pterygoid flange. Caseids (FMNH UC 1011, Maddin *et al. 2*008), araeoscelidians

(Reisz 1981, Vaughn 1955), *Mesenosaurus* (Reisz and Berman 2001), procolophonids (e.g. *Owenetta*, Reisz and Scott 2002) and *Claudiosaurus* (Carroll 1981) are the only taxa herein coded as state (1). The unusual transverse process of the pterygoid found in bolosaurids, where the transverse process remains in the same plane as the palatal process of the pterygoid, unlike all other early amniotes where the transverse process has a ventral inclination, is scored as state (2) in *Belebey* and *Eudibamus* (Reisz *et al. 2*007, Modesto *et al. 2*017).

Unambiguous: *Claudiosaurus germaini* (0to1), *Eudibamus cursoris* + *Belebey vegrandis* (0to2), *Deltavjatia rossicus* (0to1), *Nyctiphruretus* + Procolophonoidea (0to1), Araeoscelidia (0to1), Caseidae (0to1), *Mesenosaurus romeri* (0to1)

144. Pterygoid, anterior extent of palatal process: terminates anteriorly level with or posterior to the anterior margin of the palatine (0); extends anterior to the palatine (1)

Modified and polarity reversed from Laurin and Reisz (1995 c.44), deBraga and Rieppel (1997 c.76), Müller (2004 c.139), Ezcurra *et al. (*2014 c.140), Laurin and Piñeiro (2017 c.44)

State (0) is present in *Gephyrostegus* (Klembara *et al. 2*014), *Tseajaia* (Moss 1972), most synapsids and all parareptile terminal taxa herein in which the anterior portion of the palate can be observed. State (1) is found in *Seymouria* (Klembara *et al. 2*005), *Limnoscelis* (Berman *et al. 2*010), *Protorothyris* (MCZ 1532), *Petrolacosaurus* (Reisz 1981), *Orovenator (*Ford and Benson 2018), *Archaeovenator* (KUVP 12483, Reisz and Dilkes 2003) and captorhinids (Reisz *et al. 2*016, Heaton 1979).

Unambiguous: Parareptilia (1to0). DELTRAN: Reptilia (0to1), *Seymouria* spp (0to1), *Limnoscelis paludis* (0to1), *Mesenosaurus romeri* (1to0). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to0), Synapsida (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1), *Tseajaia campi* (1to0)

145. Pterygoids, median contact between each other: median contact present only anteriorly (0); median contact extensive, pterygoids meet medially along > 50% of their anteroposterior length (1); no median contact between the pterygoids (2)

Modified from Dilkes (1998 c.126), Ezcurra *et al. (*2014 c.137), Pritchard *et al. (*2015 c.52)

The paired palatal flanges of the pterygoids make contact on the midline (states 0 or 1) in all terminal taxa with the exception of early archosauromorphs (state 2) (Modesto and Sues 2004, Ezcurra and Butler 2015). The median contact of the pterygoids is extensive (state 0) in ophiacodontids (Berman *et al.*1995, Romer and Price 1940), sphenacodontians (Reisz 1986, Reisz *et al.*1992, Laurin 1993), mycterosaurines (Anderson and Reisz 2004, Reisz and Berman 2001), *Orovenator* (Ford and Benson 2018), and some parareptiles (Reisz *et al. 2*007, Tsuji 2006).

Unambiguous: Pareiasauria + Nycteroleteridae (0to1), *Ennatosaurus tecton* (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1), Archosauromorpha (0to2), *Belebey vegrandis* (0to1), *Mesosaurus tenuidens* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontia (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to2), Parareptilia except Mesosauridae and Bolosauria (1to0), Neodiapsida (1to0), Varanopidae + Neoreptilia (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

146. Pterygoid, quadrate ramus, medial shelf ('posteromedian flange'; 'tympanic flange';'arcuate flange'): absent (0); present (1)

Modified from Benson (2012 c.120) modified from Brinkman and Eberth (1983 c.14); Reisz (1986 table 3d), Reisz *et al. (*1992 c.37), Laurin (1993 c.40), Berman *et al. (*1995 c.46), Fröbisch et *al. (*2011 c.102), MacDougall and Reisz (2014 c.65), Modesto *et al. (*2015 c.65)

A medial transverse shelf extends from the ventral edge of the quadrate ramus (state 1) in all araeoscelidian and neodiapsid terminal taxa herein, with the exception of *Petrolacosaurus*, where the ventral edge forms a thickened ridge only (Reisz 1981). It is present in parareptiles where the quadrate ramus of the pterygoid can be observed. In *Archaeovenator* the medial shelf of the right quadrate ramus is present, exposed adjacent to the crista ventrolaterales of the parabasisphenoid in KUVP 12483. State (1) is also present in *Varanops* (Romer and Price 1940), *Apsisaurus* (Laurin 1991), *Aerosaurus* (Langston and Reisz 1981), caseasaurs and *Ophiacodon* (*Eothyris* MCZ 1161, Brinkman and Ebert 1983). The shelf is probably absent (state 0) in *Mesenosaurus*, where the thickened ventral edge of the vertical lamina is smoothly rounded (Reisz and Berman 2001). The quadrate ramus has a rounded ventral edge, with no trace of a medial shelf (state 0) in sphenacodontids and *Edaphosaurus* (Brinkman and Ebert 1983). The shelf is also absent in *Varanosaurus* (FMNH PR 1670), in the protorothyridids *Paleothyris* and *Protorothyris*, and in captorhinids, except *Euconcordia* (Müller and Reisz 2005).

Unambiguous: *Ophiacodon* spp (0to1), *Mesenosaurus romeri* (1to0). DELTRAN: *Mesosaurus tenuidens* (1to0), Varanopidae + Neoreptilia (0to1), *Euconcordia cunninghami* (0to1), *Limnoscelis paludis* (0to1), Caseasauria (0to1), *Araeoscelis* spp (0to1). ACCTRAN: Mesosauridae (1to0), 'protorothyridids' (1to0), Captorhinidae except *Euconcordia* (1to0), Amniota + Diadectomorpha (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to0), *Petrolacosaurus kansensis* (1to0)

147. Pterygoid, teeth on the quadrate flange: absent (0); present (1)

From MacDougall *et al. (*2018 c.72)

In *Gephyrostegus* (Klembara *et al. 2*014) and some parareptiles (e.g. *Colobomycter pholeter*, Feeserpeton and *Delorhynchus*, MacDougall *et al. 2*018 c.72) teeth extend posteromedially from the transverse flange of the pterygoid on to the anteroventral surface of the quadrate ramus of the pterygoid (state 1). This feature is absent in all other taxa included in this study (state 0).

Unambiguous: *Colobomycter pholeter* (0to1),DELTRAN: *Gephyrostegus bohemicus* (0to1). ACCTRAN: *Gephyrostegus bohemicus* (0to1)

148. Pterygoid, ascending dorsal lamina of the anterior (palatal) ramus: absent or low (0); tall (1)

From Reisz *et al. (*1992 c.36), Berman *et al. (*1995 c.45), Fröbisch et *al. (*2011 c.101), Benson (2012 c.116), Spindler *et al. (*2018 c.71)

State (1) of this character is present in sphenacodontians (Romer and Price 1940, *Haptodus* ROM 34602), edaphosaurids (*Ianthasaurus* ROM 59933, Modesto 1995) and *Ophiacodon* (Romer and Price 1940).

Unambiguous: Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1).

149. Pterygoid, anterior extent of interpterygoid vacuity: reaches beyond posterior margin of palatine (0); reaches level of palatine or less (1)

Modified from Laurin and Reisz (1995 c.39), Reisz *et al. (*2007 c.127), MacDougall and Reisz (2014 c.61), Modesto *et al. (*2015 c.61)

An anteroposteriorly short interpterygoid vacuity is present in ophiacodontids, sphenacodontians, edaphosaurids and the caseid *Ennatosaurus* (Maddin *et al. 2*008, Olson 1968). It is also found in parareptiles (Tsuji 2006, Reisz *et al. 2*007, MacDougall *et al. 2*017).

Unambiguous: Pareiasauria + Nycteroleteridae (0to1), *Colobomycter pholeter* (0to1), *Thuringothyris mahlendorffae* (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Ennatosaurus tecton* (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: Bolosauria (0to1), Synapsida (0to1), Casea broilii (1to0)

150. Ectopterygoid: present and alary process of jugal absent (0); absent and alary process of the jugal also absent (1); ectopterygoid absent and alary

process of the jugal present, but no higher than the midpoint of the suborbital process of the jugal and distinct rom the orbital margin (2); ectopterygoid absent and alary process of the jugal present and positioned on the medial surface of the jugal, flush with the orbital margin (3)

From Modesto *et al. (*2018 c.40), modified from Gauthier *et al. (*1988 c.55), Carroll and Currie (1991 c.33b), Laurin and Reisz (1995 c.47), Dodick and Modesto (1995 c.17), deBraga and Rieppel (1997 c.81 in part), Müller (2004 c.34), Sumida *et al. (*2010 c.24), Modesto *et al. (*2015 c.77).

The absence of the ectopterygoid is synapomorphy of derived captorhinids (i.e. excluding *Thuringothyris* and *Euconcordia*). In these taxa it is replaced with a medial 'alary' process of the jugal (Lauren and Reisz 1995, Heaton 1979, Reisz *et al. 2*016), which is further differentiated in its location on the medial surface (states 2 and 3). The ectopterygoid is also absent in *Mesosaurus* (Modesto 2006), although an alary process is not present (state 1).

Unambiguous: *Captorhinus aguti* + *Captorhinus laticeps* (2to3). DELTRAN: *Mesosaurus tenuidens* (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to2). ACCTRAN: Mesosauridae (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to2)

151. Ectopterygoid, dentition: present (0); absent (1); inapplicable, ectopterygoid absent (-)

From Gauthier *et al. (*1988 c.122), Laurin and Reisz (1995 c.48), Berman *et al. (*1995 c.72), deBraga and Rieppel (1997 c.81 in part), Reisz *et al. (*2007 c.48), Benson (2012 c.124), Klembara *et al. (*2014 c.67/68), Modesto *et al. (*2015 c.76)

Teeth are present on the ventral surface of the ectopterygoid in *Gephyrostegus* and *Seymouria* (Klembara *et al. 2*014, 2005), *Protorothyris* (MCZ 1532), araeoscelidians diapsids (e.g. *Petrolacosaurus*, Reisz 1981; *Araeoscelis*, Vaughn 1955) and *Orovenator (*Ford and Benson 2018). They are also present in several derived early synapsids (e.g. *Dimetrodon*, Romer and Price 1940; *Edaphosaurus*, Modesto 1995) and the caseid *Ennatosaurus* (Olson 1968, although not confirmed by Maddin *et al. 2*008).

Unambiguous: Varanopidae + Neoreptilia (0to1), *Orovenator mayorum* (1to0). DELTRAN: *Labidosaurus hamatus* (0to1), Diadectomorpha (0to1), *Varanosaurus acutirostris* (0to1), *Secodontosaurus obtusidens* (0to1), *Haptodus garnettensis* (0to1). ACCTRAN: Reptilia except Captorhinidae (1to0), Amniota + Diadectomorpha (0to1), *Dimetrodon* spp (1to0), Edaphosauridae (1to0), Caseasauria (1to0)

152. Ectopterygoid, contact restricted to maxilla: present (0); absent, ectopterygoid contacts the jugal (1); inapplicable, ectopterygoid absent (-)

From Dilkes (1998 c.40), Müller (2004 c.94), Ezcurra *et al. (*2014 c.144), Ezcurra (2016 c.142)

This character has been used principally to describe the lateral sutural contact of the ectopterygoid in archosauromorphs, in which contact with the maxilla (state 0) has been considered to be the derived state (Dilkes 1998). Nevertheless, contact with the maxilla (state 0) is also present in stem-group amniotes such as *Tseajaia*, *Limnoscelis* and *Gephyrostegus* (Moss 1972, Berman *et al. 2*010, Klembara *et al. 2*014) and early synapsids (e.g. *Dimetrodon* and *Ophiacodon,* Romer and Price 1940; *Secodontosaurus*, Reisz *et al.*1992, and *Varanosaurus*, Berman *et al.*1995). In varanopids, the lateral margin of the ectopterygoid is rarely exposed. It appears to contact the maxilla in *Mesenosaurus* (Reisz and Berman 2001), but in *Archaeovenator* (KUVP 12483) the right ectopterygoid, which is preserved in articulation with the surrounding elements of the palate and the maxilla, is located posterior to the posterior extremity of the maxilla, and therefore was probably limited to lateral contact with the jugal (state 1), as in *Orovenator (*Ford and Benson 2018). Contact is also restricted to the jugal in *Ennatosaurus* (Maddin *et al. 2*008), *Edaphosaurus* (Modesto 1995) and in *Petrolacosaurus* and neodiapsids (Reisz 1981, Carroll 1981, Gow 1975). State (1) is present in *Macroleter* (Tsuji 2006), but absent in other parareptiles.

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), Neodiapsida (0to1), *Thuringothyris mahlendorffae* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Emeroleter levis (*0to1), *Macroleter poezicus* (0to1), *Ennatosaurus tecton* (0to1), *Edaphosaurus boanerges* (0to1). ACCTRAN: *Deltavjatia rossicus* (1to0), Pareiasauria + Nycteroleteridae (0to1), Edaphosauridae (0to1), Caseasauria (0to1)

153. Suborbital opening: absent (0); present (1)

From Laurin (1991 A.3), Carroll and Currie (1991 c.3), Laurin and Reisz (1995 c.49 in part), Rieppel (1999 c.43), Müller (2004 c.32), Reisz *et al. (*2010 c.48), Klembara *et al. (*2014 c.83), Modesto *et al. (*2015 c.79)

The presence of a suborbital fenestra has long been considered a synapomorphy of Diapsida (sensu Benton 1985, Carroll and Currie 1991). Captorhinids and parareptiles possess a small foramen close to, or forming part of, the junction of the palatine, pterygoid and ectopterygoid (if present), and the presence of an opening of any size in this area has been suggested as a synapomorphy of Reptilia (Laurin and Reisz 1995), although the opening is absent in 'protorothyridids' (e.g. *Protorothyris*, Clark and Carroll 1973). *Seymouria sanjuanensis* possesses an elongate fenestra between the palatine, ecopterygoid and maxilla (Klembara *et al. 2*005), which is absent in S. *baylorensis* (Laurin 1996, White 1939) and other stem-group amniotes such as diadectomorphs (Moss 1972, Berman *et al. 2*010) and *Gephyrostegus* (Klembara *et al. 2*014). This current character describes the presence or absence of a suborbital opening, regardless of size, and the following character (ch.154) describes the morphology of this opening.

Unambiguous: *Seymouria* spp (0to1), *Orovenator mayorum* (0to1). DELTRAN: Neoreptilia (0to1), Araeoscelidia (0to1), Captorhinidae (0to1). ACCTRAN: Varanopidae (1to0), 'protorothyridids' (1to0), Reptilia (0to1)

154. Suborbital opening, morphology if present: present as anteroposteriorly elongate fenestra (0); present as small foramen (1); inapplicable, opening absent (-)

Modified from Laurin and Reisz (1995 c.49 in part), Tsuji (2006 c.57), Reisz *et al. (*2007 c.49)

Unambiguous: Captorhinidae (0to1). DELTRAN: Parareptilia except Mesosauridae (0to1). ACCTRAN: Parareptilia (0to1)

155. Quadrate, jaw articulation position (anteroposterior aspect): approximately level with occiput (0); posterior to occiput (1); anterior to occiput (2)

Modified from Laurin (1993 c.46), Laurin and Reisz (1995 c.36), Tsuji (2006 c.37), Maddin *et al. (*2008 c.46), Fröbisch et *al. (*2011 c.34), Benson (2012 c.10)

The jaw articulation is located anterior to the position of the occiput (state 2) in ankyramorph parareptiles (Tsuji 2006, deBraga and Reisz 1996, Carroll and Lindsey 1985) and the caseid *Ennatosaurus* (Maddin *et al. 2*008). This contrasts with the condition in most other early amniotes, in which the jaw articulation and occiput are approximately level with each other (state 0). In varanodontines (Langston and Reisz 1981) and ophiacodontids (Romer and Price 1940, FMNH PR 1670), *Labidosaurus* (Modesto *et al.* 2007) and *Proterosuchus* (Ezcurra 2016) the jaw articulation is posterior to the occiput (state 1).

Unambiguous: *Proterosuchus* spp (0to1), Parareptilia except Mesosauridae and Bolosauria (0to2), *Labidosaurikos meachami* + *Labidosaurus hamatus* (0to1), *Tseajaia campi* (0to1), *Ennatosaurus tecton* (0to2). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1), Ophiacodontidae (0to1)

156. Quadrate, jaw articulation position (dorsoventral aspect): at level of alveolar margin of maxillary tooth row (0); quadrate projects far ventral to

level of alveolar margin of maxillary tooth row (1)

Modified from Laurin (1993 c. 54), Modesto (1995 c.15), Mazierski and Reisz (2010 c.16), Fröbisch et *al. (*2011 c.40, c.122), Benson (2012 c.125).

In sphenacodontians, with the exception of *Secodontosaurus* (MCZ 1124, Reisz *et al.*1992), edaphosaurids, *Araeoscelis* (Reisz *et al.*1984) and *Procolophon* (Carroll and Lindsay 1985) the point of articulation between the quadrate condyle and the mandible is ventral (state 1) to the lowest point of the alveolar margin of the maxillary tooth row.

Unambiguous: *Procolophon trigoniceps* (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontia + Edaphosauridae (0to1), *Araeoscelis* spp (0to1). DELTRAN: *Deltavjatia rossicus* (0to1). ACCTRAN: *Emeroleter levis +* *Deltavjatia rossicus* (0to1)

157. Quadrate, condyles: distinct, separate (0); confluent, forming a saddle-shaped articular facet (1)

Modified from Laurin and Reisz (1995 c.65), Modesto (1995 c.14), Mazierski and Reisz (2010 c.15), Benson (2012 c.89), Modesto *et al. (*2015 c.51)

Modesto (1995) described the derived condition (state 1) as 'yoke-shaped' in posterior view rather than anteroposteriorly elongate rounded ridges. Both *Edaphosaurus* (Modesto 1995) and *Ianthasaurus* (Mazierski and Reisz 2010) are scored as possessing state (1), which is also present in some parareptiles (Modesto *et al. 2*015).

Unambiguous: Erpetonyx arsenaultorum (0to1), Ankyramorpha (0to1), Edaphosauridae (0to1). DELTRAN: *Owenetta kitchingorum* (1to0). ACCTRAN: Owenettidae (1to0)

158. Quadrate, slope of occipital margin: approximately vertical (0); inclined anterodorsally by 10-55 degrees (1); strongly inclined anterodorsally by >60 degrees (2); inclined posterodorsally (3)

Modified from Modesto (1994 c.20), Reisz *et al. (*1998 c.27), Sidor and Hopson (1998 c.42), Maddin *et al. (*2006 c.34, 2008 c.41), Reisz *et al. (*2009 c.50), Campione and Reisz (2010 c.34), Reisz *et al. (*2010 c.56), Benson (2012 c.90), Spindler *et al. (*2018 c.12)

In the current taxon list, the occipital margin is vertical (state 0) in most early amniotes, including sphenacodontians (Romer and Price 1940, Reisz *et al.*1992, Laurin 1993), edaphosaurids (Modesto *et al.* 1995) most 'protorothyridids' (Carroll 1964, 1969), araeoscelidians and neodiapsids (Reisz 1981, Reisz *et al.*1984), with the exception of *Proterosuchus* (e.g. *P. fergusi* Ezcurra *et al. 2*015), and many parareptiles (Gow 1972, deBraga and Reisz 1996). The occipital margin is also vertical in *Archaeovenator* (Reisz and Dilkes 2003 fig.3, Reisz *et al. 2*009 c.50) and *Mycterosaurus* (Berman and Reisz 1982), although anterodorsally inclined (state 1) in other varanopids (e.g. *Elliotsmithia*, Modesto *et al. 2*001; *Ascendonanus*, Spindler *et al. 2*018), and strongly inclined (state 2) in varanodontines (e.g. *Varanodon*, FMNH UR 986; *Varanops*, MCZ 1926). The parareptiles *Owenetta* (Reisz and Scott 2002), *Procolophon* (Carroll and Lindsey 1985) and *Colobomycter* (MacDougall *et al. 2*017) have slightly posterodorsally inclined occipital margins (state 3).

Unambiguous: Varanodontinae (0to2), *Ascendonanus nestleri* (0to1), *Proterosuchus* spp (0to1), Reptilia (1to0), *Limnoscelis paludis* (1to0), Sphenacodontia + Edaphosauridae (1to0), *Paleothyris acadiana* (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1). DELTRAN: *Colobomycter pholeter* (0to3), Ankyramorpha except Lanthanosuchoidea (0to3). ACCTRAN: *Acleistorhinus pteroticus* (3to0), Ankyramorpha (0to3)

159. Quadrate, shape: straight posteriorly (0); shallowly emarginated (1)

From Laurin (1991 E.7), deBraga and Rieppel (1997 c.38), Rieppel (1999 c.37), Müller (2004 c.26), Reisz *et al. (*2010 c.55), Pritchard *et al. (*2015 c.41), Ezcurra (2016 c.176)

In archosauromorphs a shallow emargination of the posterior margin of the quadrate probably provides attachment for the tympanum (Modesto and Sues 2004, Ezcurra and Butler 2015).

DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1)

160.Temporal 'otic' notch: absent (0), present (1)

Modified from Müller and Tsuji (2007 c. 134), MacDougall and Reisz (2014 c.59), Modesto *et al. (*2015 c.59)

The emargination of the posterior margin of the temporal region of the skull (state 1) is present in the stem-group amniote *Seymouria* (e.g. *Seymouria sanjuanensis* Klembara *et al. 2*005; S. *baylorensis*, Laurin 1996), and derived parareptiles such as procolophonoids (e.g. *Procolophon*, Carroll and Lindsey 1985; *Owenetta*, Reisz and Scott 2002) and nycteroleterids (e.g. *Baskyroleter mesenis*, Müller and Tsuji 2007). The emargination is formed principally by a concavity in the posterior margin of the squamosal and a posterior extension of the supratemporal. In parareptiles, the emargination of the posterior margin of the temporal region has been linked to the possession of impedance-matching hearing (Müller and Tsuji 2007).

Unambiguous: *Candelaria barbouri* (1to0), Ankyramorpha except

Lanthanosuchoidea (0to1), *Seymouria* spp (0to1)

161. Stapes, stapedial foramen: present (0); absent (1)

From Laurin (1991 E.9), Laurin and Reisz (1995 c.66), Reisz *et al. (*2010 c.66), Pritchard *et al. (*2015 c.77), Ezcurra (2016 c.297)

A perforating foramen close to the footplate of the stapes is present in most terminal taxa. The loss of the stapedial foramen has been considered a synapomorphy of archosauromorphs (Ezcurra 2016). However, Olson (1968) notes it is absent in *Casea broilii*.

DELTRAN: Archosauromorpha (0to1), Caseidae (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Caseasauria (0to1)

162. Stapes, dorsal process: present as a clearly defined process (0); absent or greatly reduced (1)

Modified from Reisz *et al. (*1992 c.31 state 3)

In several early synapsids (e.g. *Dimetrodon* and *Ophiacodon,* Romer and Price 1940, Reisz 1986; *Edaphosaurus*, Brinkman and Eberth 1983; *Mycterosaurus*, Berman and Reisz 1982), 'protorothyridids' (e.g. *Hylonomus*, Carroll 1964; *Paleothyris,* Carroll 1969), araeoscelidians (e.g. *Petrolacosaurus*, Reisz 1981; *Araeoscelis*, Vaughn 1955) and captorhinids (e.g. *Captorhinus aguti*, Fox and Bowman 1966) a distinct dorsal process is present on the stapes (state 0). This is absent (state 1) in *Orovenator* (Ford and Benson 2018), *Youngina* (Gardner *et al. 2*010), and in parareptiles in which the stapes is known (e.g. *Macroleter*, Müller and Tsuji 2007; *Procolophon*, Carroll and Lindsay 1985). In the mycterosaurine *Mesenosaurus*, the stapes is slender and rod-like, and the dorsal process is rudimentary (state 1) (Reisz and Berman 2001).

Unambiguous: Parareptilia except Mesosauridae and Bolosauria (0to1), *Seymouria* spp (0to1). DELTRAN: Neodiapsida except *Claudiosaurus* (0to1), *Orovenator mayorum* (0to1), *Mesenosaurus romeri* (0to1). ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), Neodiapsida (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1)

163. Stapes, dorsal process, articulation with the paroccipital process of the opisthotic: absent (0); present (1); inapplicable, dorsal process is absent or greatly reduced (-)

From Brinkman and Eberth (1983 c.6), Gauthier *et al. (*1988 c.69), Reisz *et al. (*1992 c.39).

Reisz (1986) described the presence of a dorsal process of the stapes that contacts the paroccipital process of the opisthotic as a synapomorphy shared by ophiacodontids, sphenacodontians and edaphosaurids. However, in *Varanosaurus* the dorsal process contacts the tabular rather than the paroccipital process (state 0) (Berman *et al.*1995). The dorsal process of the stapes articulates with the conjoined margin of the prootic and opisthotic in *Araeoscelis* (Vaughn 1955) and is scored as (0) herein. There is a small depression on the ventral margin of the opisthotic in *Euconcordia* that may have received the dorsal process of the stapes (Müller and Reisz 2005), which we score as state (1). In *Labidosaurikos,* the stapedial columella is sutured to the opisthotic (Dodick and Modesto 1995), and contact between the dorsal process and paroccipital process of the opisthotic is likely.

Unambiguous: *Varanosaurus acutirostris* (1to0). DELTRAN: Mycterosaurinae + Varanodontinae (1to0), Caseidae (1to0). ACCTRAN: Varanopidae + Neoreptilia (1to0), Caseasauria (1to0)

164. Mandible, proportions (not including laminar portion of the angular): inter- mediate proportions, dorsoventral height 0.20-0.26 of total length (0); short and robust, dorsoventral height >0.30 of total length (1); very long and dorsoventrally slender, maximum height <0.18 of total length (2)

From Benson (2012 c.126) modified from Modesto (1995 c.20), Mazierski and Reisz (2010 c. 22), Sidor (2003 c.3), Spindler *et al. (*2018 c.85)

Short, robust mandibles (state 1) are present in terminal taxa with adaptations for advanced herbivory (e.g. *Ennatosaurus*, Maddin *et al. 2*008; *Edaphosaurus*, Modesto 1995; *Procolophon*, Carroll and Lindsey 1985). Most captorhinids, sphenacodontians, with the exception of *Secodontosaurus*, and parareptiles are scored as possessing state (0). State (2) is present in ophiacodontids, varanopids, 'protorothyridids', *Petrolacosaurus*, neodiapsids and the parareptiles *Mesosaurus* (Modesto 2006) and *Owenetta* (Reisz and Scott 2002).

Unambiguous: *Procolophon trigoniceps* (2to1), *Nyctiphruretus* + Procolophonoidea (1to2), Parareptilia except Mesosauridae (2to0), Reptilia except Captorhinidae (0to2), *Euromycter rutena* + *Ennatosaurus tecton* (0to1), *Secodontosaurus obtusidens* (0to2), *Edaphosaurus boanerges* (0to1), Ophiacodontidae (0to2), *Araeoscelis* spp (2to0). DELTRAN: *Deltavjatia rossicus* (0to1). ACCTRAN: Ankyramorpha except Lanthanosuchoidea (0to1)

165. Mandible, anterodorsal curvature of anterior mandible in lateral view: absent, alveolar margin of anterior mandible approximately horizontal (0); present, dorsal margin of anterior mandible shows distinct concavity (1)

NEW

In *Gephyrostegus* (Klembara *et al.* 2014), *Seymouria* (Laurin 1996) and early 'protorothyridids' (e.g. *Hylonomus lyelli*, NHM R 4168, Carroll 1964) the anterior region of the mandible curves dorsally. This character is independent of the convexity of the ventral margin of the maxilla (ch.44), although also present in ophiacodontids and sphenacodontids.

Unambiguous: *Proterosuchus* spp (0to1), *Labidosaurus hamatus* (0to1), Amniota + Diadectomorpha (1to0), Sphenacodontia except *Haptodus* (0to1), Ophiacodontidae (0to1), *Hylonomus lyelli* (0to1)

166. Mandible, posterior region: rectilinear in lateral view (0); acumate in lateral view (1)

From Modesto *et al.* (2007 c29), Reisz *et al.* (2011 c.30), Modesto *et al.* (2014 c.60), Modesto *et al.* (2018 c.60)

Unambiguous: Owenettidae (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (0to1), Diadectomorpha (0to1). DELTRAN: Archosauromorpha (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1), *Lanthanolania* + Archosauromorpha (0to1)

167. Mandible, position of coronoid eminence: posteriorly, within posterior 1/3 of total length (0); anteriorly, approximately 2/5 of total length from posterior end (1)

From Benson (2012 c.129), Maddin *et al.* (2008 c.59)

The coronoid eminence is located further anteriorly on the mandible in caseasaurs, captorhinids, *Edaphosaurus* (Maddin *et al.* 2008) and procolophonoids (e.g. *Procolophon*, Carroll and Lindsey 1985). This character is independent of the scores for the proportions of the mandible (ch.164).

Unambiguous: *Edaphosaurus boanerges* (0to1), Caseasauria (0to1). DELTRAN: *Deltavjatia rossicus* (0to1), Procolophonoidea (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1). ACCTRAN: *Nyctiphruretus acudens* (1to0), Ankyramorpha except Lanthanosuchoidea (0to1), Captorhinidae (0to1)

168. Mandible, shape of coronoid eminence: slightly convex or low (0); strongly convex (1); subhorizontal/flat (2); dorsoventrally tall (3)

Benson (2012 c.130) modified from Reisz *et al.* (1992 c.51), Laurin (1993 c.53), Berman *et al.* (1995 c.61), Fröbisch et *al.* (2011 c.39), Spindler *et al.* (2018 c.89)

Most terminal taxa have a low coronoid eminence, which is little more than a slight to moderate convexity along the dorsal margin of the mandible, posterior to the tooth row (state 0). In *Varanops* (Campione and Reisz 2010) and *Varanodon* (FMNH PR 1670) the coronoid region of the mandible is flat (state 2). Sphenacodontians and edaphosaurs have a strongly convex coronoid eminence (state 1). *Procolophon* (Carroll and Lindsay 1985), *Owenetta* (Reisz and Scott 2002) and some bolosaurid parareptiles (e.g. *Belebey*, Reisz *et al. 2*007; *Eudibamus*, Berman *et al. 2*000) possess a coronoid eminence that is noticeably tall (state 3)

Unambiguous: *Eudibamus cursoris* + *Belebey vegrandis* (0to3), Procolophonoidea (0to3), Amniota + Diadectomorpha (1to0), Sphenacodontia + Edaphosauridae (0to1). DELTRAN: *Deltavjatia rossicus* (0to1), Varanodontinae except *Aerosaurus wellesi* (0to2). ACCTRAN: Varanodontinae (0to2), Pareiasauria + Nycteroleteridae (0to1)

169. Mandible, contribution of dentary to coronoid eminence: absent (0); present (1); inapplicable, coronoid eminence absent (-)

Modified from Laurin and Reisz (1995 c.79), deBraga and Rieppel (1997 c.83), Tsuji *et al. (*2012 c.87), Modesto *et al. (*2015 c.120), Schoch and Sues (2015 c.83), Ezcurra (2016 c.261)

Character state (1) is present in sphenacodontians (e.g. *Dimetrodon*, Romer and Price 1940; *Secodontosaurus*, Reisz *et al.*1992), parareptiles (e.g. *Stereosternum*, Modesto 1999, *Belebey*, Reisz *et al. 2*006; *Milleretta*, Gow 1972 and *Nyctiphruretus*, Säilä 2010) and the araeoscelidian diapsid *Araeoscelis* (Reisz *et al.*1984).

Unambiguous: Parareptilia (0to1), *Cutleria wilmarthi* (0to1), *Haptodus garnettensis* (0to1), *Araeoscelis* spp (0to1). DELTRAN: *Deltavjatia rossicus* (1to0), Procolophonoidea (1to0). ACCTRAN: *Nyctiphruretus acudens* (0to1), Ankyramorpha (1to0)

170. Mandible, retroarticular process: absent (0); present (1)

From Carroll and Currie (1991 c.44), Laurin (1991 B.6), Laurin (1993 c.61 in part), Berman *et al. (*1995 c.64 in part), deBraga and Rieppel (1997 c.92), Dilkes (1998 c.74 in part), Rieppel (1999 c.48), Müller (2004 c.35), Maddin *et al. (*2006 c.41), Tsuji (2006 c.85 in part), Benson (2012 c.132), Modesto *et al. (*2015 c.115), Pritchard *et al. (*2015 c.86), Spindler *et al. (*2018 c.98)

The retroarticular process of the mandible is absent in diadectomorphs (Moss 1972, Berman *et al. 2*010), caseasaurs (Reisz *et al. 2*009, Reisz and Fröbisch 2014), most ‘protorothyridids’ (Carroll 1969, Clark and Carroll 1973), araeoscelidians (Reisz 1981, Vaughn 1955) and early captorhinids (Müller and Reisz 2005, Sumida *et al. 2*010). The absence of a clearly defined retroarticular process in ophiacodontids has been noted in previous studies (e.g. Reisz *et al.*1992; Reisz and Dilkes 2003). The retroarticular process is present (state 1) in some stem-amniotes (e.g. *Seymouria*, Laurin 1996), sphenacodontians (e.g. *Dimetrodon*, Romer and Price 1940; *Haptodus*, Laurin 1993), *Edaphosaurus* (Modesto 1995) neodiapsids (e.g. *Acerosodontosaurus*, Bickelmann *et al. 2*009; *Prolacerta*, Modesto and Sues 2004), some captorhinids (e.g. *Captorhinus*, Heaton 1979) and most parareptiles (e.g. *Stereosternum*, Modesto 1999, *Mesosaurus*, Modesto 2006; *Macroleter*, Tsuji 2006; *Acleistorhinus*, deBraga and Reisz 1996; *Procolophon*, Carroll and Lindsay 1985). The presence of a small retroarticular process has been questioned in early varanopids (Reisz *et al. 2*010, Benson 2012). However, a small process is present in *Archaeovenator* (KUVP 12483, Reisz and Dilkes 2003) and *Ascendonanus* (Spindler *et al. 2*018). Indeed, the process is present but poorly developed in mycterosaurines (Reisz and Berman 2001, Botha-Brink and Modesto 2009) and varanodontines (Langston and Reisz 1981, FMNH UR 986).

Unambiguous: *Claudiosaurus germaini* (1to0), *Eudibamus cursoris* + *Belebey vegrandis* (1to0), Varanopidae + Neoreptilia (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to1), *Seymouria* spp (0to1), Sphenacodontia + Edaphosauridae (0to1)

171. Mandible, retroarticular process if present, size: small (0); large (1); inapplicable, process is absent (-)

Modified from Laurin (1991 E.10), Laurin (1993 c.61 in part,) Laurin and Reisz (1995 c.76), Dilkes (1998 c.74 in part), Tsuji (2006 c.85 in part), Reisz *et al. (*2010 c.63), Modesto *et al. (*2015 c.116)

The retroarticular process is large in sphenacodontids (Romer and Price fig.16, Reisz *et al.*1992), archosauromorphs (Gow 1975, Ezcurra and Butler 2005), and some early parareptiles and procolophonoids (Modesto 2006, Modesto *et al. 2*015, Reisz and Scott 2002).

Unambiguous: *Nyctiphruretus* + Procolophonoidea (0to1), *Mesosaurus tenuidens* (0to1). DELTRAN: Archosauromorpha (0to1), Erpetonyx arsenaultorum (0to1), Sphenacodontidae (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Bolosauria (0to1), Sphenacodontia except *Haptodus* (0to1)

172. Mandible, retroarticular process, composition: composite, formed by articular, angular and surangular (0); formed only by articular (1); inapplicable process is absent (-)

Modified from Laurin (1991 J.5), Laurin and Reisz (1995 c.77), Berman *et al. (*1995 c.64 in part), Dilkes (1998 c.74 in part), Tsuji (2006 c.86), Maddin *et al. (*2006 c.41 in part), Reisz *et al. (*2010 c.64), Benson (2012 c.133 in part), Modesto *et al. (*2015 c.117), Pritchard *et al. (*2015 c.87)

Unambiguous: *Nyctiphruretus* + Procolophonoidea (1to0). DELTRAN: Parareptilia except Mesosauridae and Bolosauria (0to1), *Stereosternum tumidum* (0to1), Sphenacodontidae (0to1). ACCTRAN: *Mesosaurus tenuidens* (1to0), Parareptilia (0to1), Sphenacodontia except *Haptodus* (0to1)

173. Mandible, retroarticular process, orientation: posteriorly directed (0); upturned posterodorsally (1); curves posteroventrally (2) inapplicable process is absent (-)

Modified from Reisz (1986 table 3e), Gauthier *et al. (*1988 c.105), Dilkes (1998 c.75), Müller (2004 c.101), Benson (2012 c.133 in part)

A downturned retroarticular process (state 2) is present in sphenacodontians (*Dimetrodon*, *Secodontosaurus*, Reisz *et al.*1992 and *Haptodus*, ROM 92872). It is upturned (state 1) in varanodontines (e.g. *Varanodon*, Olson 1965 fig. A, FMNH UC 986) and some neodiapsids (e.g. *Prolacerta*, Gow 1975 fig.20; *Proterosuchus* Ezcurra and Butler 2015 fig. 6J). All other terminal taxa, in which the morphology can be observed, possess a posteriorly directed process (state 0).

Unambiguous: Sphenacodontia (0to2), Varanodontinae except *Aerosaurus wellesi* (0to1). DELTRAN: Neodiapsida except *Claudiosaurus* (0to1). ACCTRAN: Neodiapsida (0to1)

174. Mandible, lateral mandibular fenestra between dentary and angular: absent (0); present (1)

From Gauthier *et al. (*1988 c.87), Reisz *et al. (*1992 c.49), Berman *et al. (*1995 c.57), Dilkes (1998 c.76), Sidor (2003 c. 64), Nesbitt (2011 c.138), Benson (2012 c.137), Pritchard *et al. (*2015 c.84), Ezcurra (2016 c.261)

A lateral (or external) mandibular fenestra is present on the mandible in archosauriforms (Nesbitt 2011), represented herein only by *Proterosuchus*, and in ophiacodontids (Reisz 1972, Berman *et al.* 1995, MCZ1366).

Unambiguous: *Proterosuchus* spp (0to1). DELTRAN: Ophiacodontidae except *Echinerpeton* (0to1). ACCTRAN: Ophiacodontidae (0to1)

175. Mandible, posterior inframeckelian foramen (foramen intermandibularis caudalis): present (0); absent (1)

Modified from Laurin and Reisz (1995 c.69), Tsuji (2006 c.78), Reisz *et al. (*2007 c69), Tsuji *et al. (*2012 c.77), MacDougall and Reisz (2014 c.106), Modesto *et al. (*2015 c.106)

The posterior inframeckelian foramen is located on the medial surface of the mandible, ventral to the posterior or single coronoid, in many early amniotes (Romer 1956). It is absent in sphenacodontians (Romer and Price 1940, Reisz *et al.* 1992, *Haptodus* ROM 43602), *Araeoscelis* (Vaughn 1955) and *Mesosaurus* (Modesto 2006).

Unambiguous: Mesosauridae (0to1), Sphenacodontia (0to1). DELTRAN: *Araeoscelis* spp (0to1). ACCTRAN: Araeoscelidia (0to1)

176. Mandible, contribution of the splenial or post-splenial to the posterior inframeckelian foramen: absent (0); present (1); inapplicable, foramen is absent (-)

NEW

Character state (1) is found in stem-amniotes, most parareptiles (e.g. *Colobomycter*, MacDougall *et al. 2*017; *Procolophon*, Carroll and Lindsay 1985; *Macroleter*, Tsuji 2006), captorhinids (e.g. *Captorhinus,* Fox and Bowman 1966; *Reiszorhinus*, Sumida *et al. 2*010 fig. 2B), *Protorothyris* (Clark and Carroll 1973) and *Edaphosaurus* (Modesto 1995).

Unambiguous: Parareptilia except Mesosauridae and Bolosauria (0to1., DELTRAN: Varanopidae + Neoreptilia (1to0), Caseidae (1to0), *Varanosaurus acutirostris* + *Ophiacodon* spp (1to0).ACCTRAN: Diapsida (1to0), Synapsida (1to0), Sphenacodontia + Edaphosauridae (0to1)

177. Mandible, contribution of the prearticular to the posterior inframeckelian foramen: absent (0); present (1); inapplicable, foramen is absent (-)

NEW

The prearticular contributes to the posterior inframeckelian foramen (state 1) in stem-amniotes, neodiapsids (e.g. *Claudiosaurus*, Carroll 1981), caseids (e.g. *Ennatosaurus*, Maddin *et al. 2*008), ophiacodontids (Romer and Price 1940), *Edaphosaurus* (Modesto 1995), early varanopids (e.g. *Archaeovenator*, Dilkes and Reisz 2003*, Orovenator*, Ford and Benson 2018), varanodontines (e.g. *Aerosaurus*, Langston and Reisz 1981; *Varanops*, Campione and Reisz 2010) and some parareptiles (e.g. *Belebey*, Reisz *et al. 2*007; *Colobomycter*, MacDougall *et al. 2*017; *Procolophon*, Carroll and Lindsay 1985

Unambiguous: *Macroleter poezicus* (1to0), *Milleretta rubidgei* (1to0). DELTRAN: *Owenetta kitchingorum* (1to0), *Protorothyris archeri* (1to0). ACCTRAN: Owenettidae (1to0), 'protorothyridids' (1to0)

178. Mandible, posterior inframeckelian foramen (foramen intermandibularis caudalis), size: large, greater than 25% of jaw length (0); small, less than 16% of jaw length (1); inapplicable, foramen is absent. (-)

Modified from Maddin *et al. (*2008 c.60), Benson (2012 c.128), Spindler *et al. (*2018 c.88)

Unambiguous: Diadectomorpha (1to0). DELTRAN: *Owenetta kitchingorum* (1to0), *Colobomycter pholeter* (1to0), *Reiszorhinus olsoni* (1to0). ACCTRAN: Owenettidae (1to0), Lanthanosuchoidea (1to0), *Romeria* spp + *Reiszorhinus olsoni* (1to0)

179. Mandible, symphysis: dorsoventrally low, mandible tapers anteriorly (0); dorsoventrally thick, symphysis almost as deep as mandible at midlength of the tooth row (1)

From Maddin *et al. (*2008 c.53), Reisz *et al. (*2009 c.57), Fröbisch et *al. (*2011 c.120), Benson (2012 c.127), Spindler *et al. (*2018 c.87)

Unambiguous: *Labidosaurus hamatus* (0to1), *Reiszorhinus olsoni* (0to1), *Seymouria* spp (0to1), *Limnoscelis paludis* (0to1), Caseidae (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontia + Edaphosauridae (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Deltavjatia rossicus* (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (0to1), Bolosauria (0to1)

180. Dentary, size: comprises equal to or greater than 70% of the anteroposterior length of the mandible (0); equal to or less than 65% (1)

From Modesto (1995 c.21), Mazierski and Reisz (2010 c.23), Benson (2012 c.134)

All caseids (e.g. *Ennatosaurus*, Maddin *et al. 2*008; *Euromycter*, Sigogneau-Russell and Russell 1974), some captorhinids (e.g. *Captorhinus laticeps*, OMNH 15101), *Edaphosaurus* (MCZ 4309, Modesto 1995 fig.17B), *Procolophon* (Carroll and Lindsay 1985), *Owenetta* (Reisz and Scott 2002) and the diadectomorph *Tseajaia* (Moss 1972) have short dentaries relative to the length of the mandible (state 1). Character state (1) can also be found in taxa with long and slender mandibles e.g. archosauromorphs.

Unambiguous: *Captorhinus aguti* + *Captorhinus laticeps* (0to1), *Romeria* spp (0to1), *Tseajaia campi* (0to1), Caseidae (0to1), *Edaphosaurus boanerges* (0to1). DELTRAN: Archosauromorpha (0to1), *Deltavjatia rossicus* (0to1), Procolophonoidea (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), *Nyctiphruretus acudens* (1to0), Ankyramorpha except Lanthanosuchoidea (0to1)

181. Dentary, orientation of anteriormost marginal tooth: mainly vertically (0); leans anteriorly (1); leans strongly anteriorly, at least 45 degrees from

perpendicular of the alveolar margin (2)

Modified from Dodick and Modesto (1995 c.39), Müller and Reisz (2006 c.39), Sumida *et al. (*2010 c.48), Modesto *et al. (*2018 c.57)

This character has principally been used in studies concerned with the interrelationships of captorhinids. Some captorhinids possess vertical anterior dentary teeth (state 0, e.g. *Euconcordia* and *Protocaptorhinus*).Character state (1) is present in *Romeria* and *Reiszorhinus*, whereas state 2 is found in *Captorhinus aguti, Captorhinus laticeps* and *Labidosaurus*. We also find that the orientation of the anteriormost marginal tooth of the dentary varies within other groups of early amniotes. Reisz (1981) noted a slight anterior inclination of the first three teeth on the dentary of *Petrolacosaurus*. A similar condition can be seen in *Araeoscelis* (MCZ 4380), *Orovenator (*Ford and Benson fig.13A) and in the anteriormost dentary tooth in *Archaeovenator* (KUVP 12483), *Elliotsmithia* (Modesto *et al. 2*001 fig.1), *Secodontosaurus* (MCZ 1124, Reisz *et al.*1992), *Haptodus* (Laurin 1993 fig.1) and in edaphosaurids (e.g. *Edaphosaurus*, MCZ 4309; *Ianthasaurus*, Mazierski and Reisz 2010 fig.2B)). Amongst parareptiles it is present in *Colobomycter pholeter* (BMRP 2008.3.1, MacDougall *et al. 2*017) and *Belebey* (Reisz *et al. 2*007). *Mesosaurus tenuidens* has a distinctively strong anterior inclination of the first dentary tooth , state 2 (Modesto 2006).

Unambiguous: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Mesosaurus tenuidens* (1to2), Araeoscelidia (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (0to2), *Romeria* spp + *Reiszorhinus olsoni 0*to1), *Dimetrodon* spp (1to0), *Elliotsmithia* longiceps (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Colobomycter pholeter* (0to1), *Stereosternum tumidum* (0to1), *Echinerpeton intermedium* (0to1), Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: Lanthanosuchoidea (0to1), Parareptilia except Mesosauridae and Bolosauria (1to0), Parareptilia (0to1), Ophiacodontidae except *Echinerpeton* (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

182. Dentary, anteroposterior length of suture with surangular in lateral view: equal to or shorter than the dentary/angular suture (0); longer that the dentary/angular suture (1)

NEW

State (1) of this character describes a posterior tapering extension of the dentary, which is sutured ventrally to a long anterior process of the surangular, such that the dentary/surangular suture is longer that the dentary/angular suture in lateral view. This state is present in some varanopids (e.g. *Orovenator*, Ford and Benson 2018, *Archaeovenator*, Reisz and Dilkes 2003, and *Mesenosaurus*, Reisz and Berman 2001), Mesosauridae (Modesto 1999, Modesto 2006), *Deltavjatia*(Tsuji 2013) and

Eothyris (Reisz *et al.* 2009)

Unambiguous: Mesosauridae (0to1).DELTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Deltavjatia rossicus* (0to1), *Eothyris parkeyi* (0to1), *Mesenosaurus romeri* (0to1). ACCTRAN: Varanodontinae (1to0), Pareiasauria + Nycteroleteridae (0to1), Varanopidae (0to1), Eothyrididae (0to1)

183. Splenial, contribution to mandibular symphysis: present, symphysis formed from dentary and splenial (0); absent, symphysis formed solely by dentary (1)

Form Berman *et al. (*1995 c.58), Maddin *et al. (*2008 c.59), Fröbisch et *al. (*2011, c 121), Benson (2012 c.138), Spindler *et al. (*2018 c.92)

The splenial participates in the mandibular symphysis in *Seymouria* (Klembara *et al. 2*005) and diadectomorphs (e.g. *Limnoscelis*, Berman *et al. 2*010). This state (0) is probably plesiomorphic for amniotes, and is present in caseids (e.g. *Euromycter*, Sigogneau-Russell and Russell 1974; *Ennatosaurus*, Maddin *et al. 2*008), captorhinids (e.g. *Thuringothyris*, Müller et *al. 2*006; *Reiszorhinus*, Sumida *et al. 2*010; *Captorhinus,* Heaton 1979), *Edaphosaurus* (Modesto 1995) and sphenacodontians (other than *Secodontosaurus*, Reisz *et al.*1992). The symphysis is formed by the dentary only in ophiacodontids, varanopids, 'protorothyridids', araeoscelidian diapsids, neodiapsids and parareptiles, with the exception of *Mesosaurus*.

Unambiguous: *Secodontosaurus obtusidens* (0to1). DELTRAN: *Deltavjatia rossicus* (1to0), *Mesosaurus tenuidens* (1to0), *Euconcordia cunninghami* (0to1), Reptilia except Captorhinidae (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: *Emeroleter levis* + *Deltavjatia rossicus* (1to0), Mesosauridae (1to0), Captorhinidae except *Euconcordia* (1to0), Reptilia (0to1), Ophiacodontidae (0to1)

184. Splenial, anterior dorsoventral height: narrow, splenial tapers anteriorly (0); deep, maintains dorsoventral height anteriorly (1)

Modified from Maddin *et al. (*2008 c.55)

In most terminal taxa the splenial narrows anteriorly as it approaches the mandibular symphysis. In *Ennatosaurus* and *Euromycter* the splenial maintains its dorsoventral height anteriorly (Maddin *et al. 2*008 c.55). A similar condition is found in *Limnoscelis* (Berman *et al. 2*010). In *Labidosaurikos* and *Labidosaurus,* the splenial contributes a dorsoventrally deep symphysial surface (Dodick and Modesto 1995, Modesto *et al.* 2007).

Unambiguous: *Labidosaurikos meachami* + *Labidosaurus hamatus* (0to1), *Euromycter rutena* + *Ennatosaurus tecton* (0to1). DELTRAN: *Limnoscelis paludis*

(0to1). ACCTRAN: Diadectomorpha (0to1)

185. Splenial, exposure on lateral surface of mandible: present (0); absent (1)

Modified from Berman *et al. (*1995 c.59), Modesto (1995 c.22), Sidor and Hopson (1998, c.90), Maddin *et al. (*2008 c.55), Mazierski and Reisz (2010 c.24), Fröbisch et *al. (*2011 c.121), Benson (2012 c.139)

Unambiguous: *Deltavjatia rossicus* (1to0), Mesosauridae (1to0), Amniota + Diadectomorpha (0to1), *Euromycter rutena* + *Ennatosaurus tecton* (1to0), Sphenacodontia + Edaphosauridae (1to0), *Araeoscelis* spp (1to0)

186. Splenial, contact with posterior coronoid: absent (0); present (1)

Maddin *et al. (*2008 c.57), Benson (2012 c.140), Spindler *et al. (*2018 c.93)

In *Ophiacodon,* contact between the posterior coronoid and splenial is prevented by a thin point contact between the anterior coronoid and the prearticular (Romer and Price 1940 plate 2), morphology very similar to that of *Varanops* (Campione and Reisz 2010 fig.3C, 3D). Therefore, both taxa are scored as state (0) herein. This is contrary to the approach of Spindler *et al. (*2018), where character state (1) is described as 'closely located to contacting' the posterior coronoid (Spindler *et al. 2*018 online resource 3, c.93), and allowed the score of *Ophiacodon* to match that of *Varanosaurus*, in which sutural contact between the posterior coronoid and splenial is present (state 1).

Parareptilia except Mesosauridae and Bolosauria (0to1), *Varanosaurus acutirostris* (0to1), *Secodontosaurus obtusidens* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Prolacerta broomi* (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Mesenosaurus romeri* (0to1).ACCTRAN: Mycterosaurinae (0to1), Neodiapsida except *Claudiosaurus* (0to1), Captorhinidae (0to1)

187. Postsplenial: present (0); absent (1)

Klembara *et al.* 2014 c.104

The postsplenial is plesiomorphically present in *Gephyrostegus* (Klembara *et al. 2*014) and *Seymouria* (Klembara *et al. 2*005). It is also present in *Petrolacosaurus* (Reisz 1981).

Unambiguous: Amniota + Diadectomorpha (0to1), *Petrolacosaurus kansensis* (1to0)

188. Coronoids, number in mandible: three (0); two (1); one (2)

Modified from Gauthier *et al. (*1988 c.100), Laurin (1993 c.55), Laurin and Reisz

(1995 c.74), deBraga and Rieppel (1997 c.84), Sidor and Hopson (1998 c.89), Müller and Reisz (2006 c.67), Maddin *et al. (*2008 c.61), Fröbisch et *al. (*2011 c.41), Benson (2012 c.141), Klembara *et al. (*2014 c.95), Modesto *et al. (*2015 c.113), Spindler *et al. (*2018 c.94)

This character describes one of the key diagnostic features that support the early divergence of amniotes into the synapsid total-group, in which two coronoids are present (state 1), and the reptile total-group, in which only a singe coronoid is present (state 2). The current paradigm suggests a single coronoid (state 2) is present in captorhinids, parareptiles (including mesosaurs), 'protorothyridids' and araeoscelidian diapsids and neodiapsids (Laurin and Reisz 1995, deBraga and Reisz 1997). We note there are exceptions to this hypothesis. Two coronoids are present in the araeoscelidian diapsid *Araeoscelis* (Vaughn 1955). Carroll (1964) described isolated edentulous anterior coronoids in two specimens, and a rugose area on the medial surface of the dentary level with the 10th tooth position in the early 'protorothyridid' *Hylonomus*. *Hylonomus* has nevertheless been scored as possessing a single coronoid in previous analyses (Müller and Reisz 2006 c.57), and here it is scored as state (1). The primitive condition, the presence of three coronoids, is only known in the early stem-group terminals *Gephyrostegus* and *Seymouria* (Klembara *et al. 2*014, Laurin 1996). Some, if not all, diadectomorphs possess just two coronoids e.g. *Limnoscelis* (Berman *et al. 2*010). Many previous analyses have scored all taxa considered to be early synapsids, including caseasaurs, sphenacodontians and edaphosaurs as possessing two coronoids (state 1), and this is supported by various descriptive studies (Sigogneau-Russell and Russell 1974, Maddin *et al. 2*008, Reisz *et al.*1992, Currie 1977, Modesto 1995). An anterior coronoid has also been described in the varanodontine *Varanops* (Campione and Reisz 2010). However, the condition in early varanopids and mycterosaurines is different, some of which seem to lack the anterior coronoid and therefore possess only a single coronoid: the anterior coronoid is absent in *Archaeovenator* (Dilkes and Reisz 2003) and *Mesenosaurus* (Reisz and Berman 2001), and these taxa are scored as state (2) herein. The condition in other varanodontines and mycterosaurines cannot be determined (reviewed by Ford and Benson 2018), and they are scored as (?) in agreement with Benson (2012).

Unambiguous: Reptilia (1to2), Amniota + Diadectomorpha (0to1), *Hylonomus lyelli* (2to1), *Araeoscelis* spp (2to1). DELTRAN: *Varanops brevirostris* (2to1). ACCTRAN: Varanodontinae (2to1)

189. Coronoid, teeth: present (0); absent (1)

From Laurin (1993 c.81), Maddin *et al. (*2008 c.62), Fröbisch et *al. (*2011 c.63), Benson (2012 c.142), Klembara *et al. (*2014 c.119/120/121), Spindler *et al. (*2018 c.95)

Amongst early amniotes coronoid teeth are present (state 0) in out-group-taxa (e.g. *Seymouria*, Laurin 1996; *Gephyrostegus*, Klembara *et al. 2*014 fig.7C), caseasaurs (Maddin *et al. 2*008, Brocklehurst *et al. 2*016), the 'protorothyridid' *Hylonomus* (Carroll 1964), the sphenacodontian *Haptodus* (ROM 43601, Laurin 1993 fig. 8D) and the edaphosaurid *Edaphosaurus* (Modesto 1995).

Unambiguous: Reptilia (0to1), *Hylonomus lyelli* (1to0). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontidae (0to1). ACCTRAN: Sphenacodontia except *Haptodus* (0to1), Ophiacodontidae (0to1)

190. Angular, cross-section shape of posteroventral border of angular: weakly developed ridge or keel (0); prominent, sheet-like keel with strongly convex posterior edge (1); reflected lamina separated from mandible by a posterior notch in lateral view (2); ridge or keel absent from ventral surface of angular (3).

Modified from Benson (2012 c.143) modified from Brinkman and Eberth (1983 c.7), Reisz *et al. (*1992 c.50), Berman *et al. (*1995 c.60/63), Reisz and Dilkes (2003 c.38), Maddin *et al. (*2006 c.40), Maddin *et al. (*2008 c.56), Reisz *et al. (*2009 c.58), Spindler *et al. (*2018 c.91)

A weakly keeled angular (state 0) is present in diadectomorphs, caseasaurs, early varanopids (including *Orovenator*), araeoscelidians, parareptiles. Ophiacodontids, edaphosaurids and *Haptodus* share state (1). State (2) is restricted to sphenacodontids. The keel is absent (state 3) in derived mycterosaurines, varanodontines, neodiapsids and captorhinids. The definition of state (3) has been revised to describe the absence of a ridge or keel rather than the presence of an evenly rounded edge e.g. Benson (2012 c.143), since the curvature of the ventral surface of the angular can differ in those taxa where the keel is absent, as noted by Spindler *et al. (*2018 c.91).

Unambiguous: Mycterosaurinae + Varanodontinae (0to3), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to3), *Seymouria* spp (0to3), Sphenacodontia except *Haptodus* (1to2), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1), *Paleothyris acadiana* (0to3). DELTRAN: Neodiapsida except *Claudiosaurus* (0to3), *Deltavjatia rossicus* (0to3). ACCTRAN: Lanthanosuchoidea (3to0), Neoreptilia (0to3)

191. Surangular, anterior extension: extends anteriorly beyond coronoid eminence (0); terminates posterior to or level with the anterior border of the coronoid eminence (1)

Modified from Laurin and Reisz (1995 c.72), deBraga and Rieppel (1997 c.86), Müller (2004 c.146), Reisz *et al. (*2007 c.72), Tsuji *et al. (*2012 c.80), Ezcurra *et al.*

*(*2014 c.162), Ezcurra (2016 c.285)

This character has more recently been used to describe morphological similarities among ankyramorph parareptiles (Tsuji *et al. 2*012 c.80) and lepidosauromorphs (Ezcurra 2016 c.285). In the current taxon list, the anterior extension of the surangular does not extend beyond the coronoid eminence (state 1) in captorhinids (Clark and Carroll 1973, Heaton 1979. Dodick and Modesto 1995, Modesto *et al.* 2007), caseids (Sigogneau-Russell and Russell 1974, Maddin *et al. 2*008) ophiacodontids (Romer and Price 190, Berman *et al.*1995) edaphosaurids (Modesto 1995), sphenacodontids (Romer and Price 1940), *Mycterosaurus* (Berman and Reisz 1982), *Heleosaurus* (Botha-Brink and Modesto 2009), *Araeoscelis* (Reisz *et al.*1984) and *Claudiosaurus* (Carroll 1981).

Unambiguous: *Claudiosaurus germaini* (0to1), *Paleothyris acadiana* (0to1), *Araeoscelis* spp (0to1), *Heleosaurus scholtzi* (0to1), *Mycterosaurus longiceps* (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Nyctiphruretus* + Procolophonoidea (0to1), *Acleistorhinus pteroticus* (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), Caseidae (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), Pareiasauria + Nycteroleteridae (1to0), Ankyramorpha (0to1), Reptilia except Captorhinidae (1to0), Amniota (0to1), Eothyrididae (1to0)

192. Surangular, anterior surangular foramen: absent (0); present (1)

From Modesto and Sues (2004 c.145), Ezcurra *et al. (*2014 c.164), Pritchard *et al. (*2015 c.80), Ezcurra (2016 c.288)

As noted by Modesto and Sues (2004) an anteriorly opening foramen and groove is located on the lateral surface of the surangular at the base of the coronoid eminence in *Prolacerta* and *Proterosuchus*, and is considered homologous with similar opening in archosaurs and squamates. It is absent in all other terminal taxa included in the analysis.

DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1).

193. Surangular, posterior surangular foramen: absent (0); present (1)

From Modesto and Sues (2004 c.146), Nesbitt (2011 c.163), Ezcurra *et al. (*2014 c.165), Pritchard *et al. (*2015 c.81), Ezcurra (2016 c.289)

This is a second opening on the surangular, located ventral to the articulating facet for the quadrate. The posterior surangular foramen is present in archosauromorphs, such as *Proterosuchus* and *Prolacerta* (Modesto and Sues 2004), nyctiphruretid parareptiles (Modesto *et al. 2*015 c.112) and *Milleretta* (Gow 1975 identified a small foramen on the posterolateral surface of the surangular in *Milleretta* as the entry point for the chorda tympani branch of cranial nerve VII).

Unambiguous: *Milleretta rubidgei* (0to1). DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1).

194. Surangular, medial expansion of dorsal surface: thin, sheet-like surangular, unexpanded (0); medially expanded along the dorsal margin, forming a broad dorsally facing platform (1).

From Benson (2012 c.145), Spindler *et al. (*2018 c.90)

This character was first introduced by Benson (2012) to describe the medial expansion of the dorsal surface of the surangular (state 1) as a varanodontine synapomorphy. State (1) is also present in *Apsisaurus* (MCZ 1474, Reisz *et al. 2*010), *Mycterosaurus* and *Orovenator (*Ford and Benson 2018 fig. 13C/13D, based on µCT data). A similar condition is also found in some neodiapsids (e.g. *Acerosodontosaurus*, Currie 1980). Laurin and Reisz (1995) described an accessory lateral shelf on the dorsal surface of the surangular in procolophonids and testudines, and Modesto *et al. (*2015 c.112) scored this feature as being present in several ankyramorph parareptiles. Here, we treat the presence of a lateral shelf as a separate morphology, which is described in the subsequent character (ch.195).

DELTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), *Acerosodontosaurus piveteaui* (0to1), *Orovenator mayorum* (0to1), *Mesenosaurus romeri* (1to0). ACCTRAN: Parareptilia (1to0), Varanopidae + Neoreptilia (0to1), *Archaeovenator hamiltonensis* (1to0), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (1to0)

195. Surangular, accessory lateral shelf anterior to articular region: absent (0); present (1)

From Laurin and Reisz (1995 c.73), Modesto *et al. (*2015 c.111)

Character state (1) is present in several ankyramorph parareptiles, including *Macroleter* and *Procolophon* (Modesto *et al. 2*015 c.111), *Nyctiphruretus* (Säilä 2010), *Emeroleter* (Tsuji 2012) and *Deltavjatia*(Tsuji 2013). In *Belebey* a ridge overhangs the mandible laterally (Reisz *et al. 2*007) which we also score as state (1). A lateral ridge is also present on the mandible of *Labidosaurus* and *Labidosaurikos* (Modesto *et al.* 2007)

Unambiguous: Ankyramorpha except Lanthanosuchoidea (0to1), *Labidosaurikos meachami* + *Labidosaurus hamatus* (0to1). DELTRAN: *Belebey vegrandis* (0to1), *Owenetta kitchingorum* (1to0). ACCTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), Owenettidae (1to0)

196. Surangular, anterodorsal process preventing posterior contact of dentary and coronoid: absent (0); present (1)

NEW

In *Seymouria* (Laurin 1996 fig.3E, MCZ 1083), ophiacodontids (Romer and Price 1940 plate 1, *Varanosaurus* FMNH PR 1670), mycterosaurines (Reisz and Berman 2001), varanodontines (Langston and Reisz 1981), *Reiszorhinus* (FMNH UC 183) and *Orovenator (*Ford and Benson 2018) a conspicuous anterodorsal process of the surangular prevents contact between the posterior region of the dentary and the coronoid on the dorsal margin of the mandible.

Unambiguous: *Reiszorhinus olsoni* (0to1), *Seymouria* spp (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1). ACCTRAN: Varanopidae (0to1), Ophiacodontidae (0to1)

197. Surangular, morphology of anterodorsal process, if present: narrow splint-like process (0); dorsoventrally broad posteriorly, tapering anteriorly (1), inapplicable, anterodorsal process absent (-)

NEW

In several terminal taxa an anterodorsal process of the surangular (ch.196), where present, is a mediolaterally narrow splint-like process, principally exposed dorsally e.g. in mycterosaurines and varanodontines (Campione and Reisz 2010, *Mycterosaurus* FMNH UC 692) and *Orovenator (*Ford and Benson 2018 fig.13A, D). In other taxa where this morphology is present the process is broad at its base and prominent in lateral view, tapering anteriorly (e.g. *Ophiacodon,* Romer and Price 1940; *Reiszorhinus*, Sumida *et al. 2*010 and *Seymouria*, Laurin 1996).

DELTRAN: Varanopidae except *Ascendonanus* (0to1). ACCTRAN: Reptilia except Captorhinidae (0to1)

198. Prearticular, medial surface: nearly straight (0); twisted posteriorly (1)

From Brinkman and Eberth (1983 c.12), Reisz (1986 table 3d), Reisz *et al. (*1992 c.52), Berman *et al. (*1995 c.62), Fröbisch et *al. (*2011 c.105), Benson (2012 c.146)

A conspicuous twisting of the posterior surface of the prearticular is present in sphenacodontians and edaphosaurs (Romer and Price 1940, Brinkman and Eberth 1983, Reisz 1986).

Unambiguous: Sphenacodontia + Edaphosauridae (0to1).

Postcranial characters

199. Vertebrae, notochordal canal: present throughout ontogeny (0); absent in adults (1)

From Gauthier *et al. (*1988 c.124), Laurin (1991: F3), deBraga and Rieppel (1997 c.99), Dilkes (1998 c.83), Rieppel (1999 c.59), Müller (2004 c.40), Reisz *et al. (*2010 c.68), Ezcurra *et al. (*2014 c.67), Schoch and Sues (2015 c.99)

The notochordal canal is closed in adults of saurians and in derived therapsids (deBraga and Rieppel 1997). In the current taxon list it is scored as (1) in *Prolacerta* and *Proterosuchus*. A continuous notochordal canal appears to be present in adult individuals of all other terminal taxa in which vertebrae have been preserved, with the exception of *Milleretta* (Gow 1972).

DELTRAN: Archosauromorpha (0to1), *Milleretta rubidgei* (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (1to0), Neoreptilia (0to1)

200. Vertebrae, presacral, count: 27 or more (0); fewer than 27 (1)

From Benson (2012 c.148), Spindler *et al. (*2018 c.105) modified from Carroll and Currie (1991 c.46), deBraga and Rieppel (1997 c. 97), Klembara *et al. (*2014 c.123), Laurin and Piñeiro (2017 c. 84)

Previous studies select different numerical boundaries between the states of this character depending on their taxonomic focus. Laurin and Piñeiro (2017) and deBraga and Rieppel (1997), for example, chose 20 presacral vertebrae as the boundary for the primitive and derived states in a broad based analyses of early amniotes focusing on turtles, whereas both Benson (2012) and Spindler *et al. (*2018) used 27 presacrals for synapsid-focused studies. Klembara *et al. (*2014) employed a multistate approach (minimum 28 to more than 38) for anamniotes, and Carroll and Currie (1991) use 26 vertebrae for diapsids. Here we use the 27 presacral count of Benson (2102) and Spindler *et al. (*2018), and find that *Seymouria* (Berman *et al. 2*000), *Gephyrostegus* (Carroll 1970) and diadectomorphs (Moss 1972, Romer 1946) have fewer that 27 presacral vertebrae, a condition that also occurs in Captorhinids (e.g. *Thuringothyris,* Müller *et al. 2*006, *Captorhinus aguti*, Fox and Bowman 1966 and *Captorhinus laticeps*, Heaton and Reisz 1980), *Petrolacosaurus* (Reisz 1981) and neodiapsids (e.g. *Youngina*, Smith and Evans 1996; *Acerosodontosaurus*, Bickelmann *et al. 2*009; *Claudiosaurus,* Carroll 1981; and *Prolacerta*, Gow 1975). Where known, all other terminal taxa share state (0), with the exception of *Casea* (Olson 1968), *Pantelosaurus* (Spindler 2016), *Eudibamus* (Berman *et al. 2*000), *Milleretta* (Gow 1972) and *Deltavjatia* (Tsuji 2013).

Unambiguous: *Deltavjatia rossicus* (0to1), *Milleretta rubidgei* (0to1), Neodiapsida

(0to1), *Pantelosaurus saxonicus* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Eudibamus cursoris* (0to1), Reptilia except Captorhinidae (1to0), *Eocasea martini* (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to0). ACCTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (0to1), Captorhinidae (0to1), Amniota (1to0), Caseidae (0to1)

201. Cervical vertebrae, atlantal ribs: present (0); absent (1)

From deBraga and Rieppel (1997 c.102), Schoch and Sues (2015 c.102)

The loss of an ossified atlantal rib (state 1) is a feature of neodiapsids (deBraga and Rieppel 1997), and is scored as absent (state 1) in *Claudiosaurus, Prolacerta* and *Proterosuchus*. However, both Currie (1980) and Bickelmann *et al. (*2009) note an articulation facet for the atlantal rib on the atlantal neural arch in *Acerosodontosaurus*. The atlantal rib is also absent in *Captorhinus laticeps* (Heaton and Reisz 1980).

DELTRAN: *Claudiosaurus germaini* (0to1), Archosauromorpha (0to1). ACCTRAN: *Acerosodontosaurus piveteaui* (1to0), Neodiapsida (0to1).

Unambiguous: *Captorhinus laticeps* (0to1). DELTRAN: Archosauromorpha (0to1), *Claudiosaurus germaini* (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (1to0), Neodiapsida (0to1)

202. Cervical vertebrae, atlas-axis complex, atlantal and axial intercentra: contact ventrally or in very close proximity (0); widely separated by ventral extension of the atlantal centrum (1)

From Benson (2012 c.150) modified from Reisz *et al. (*1992 c.67), Laurin (1993 c.89), Berman *et al. (*1995 c.73)

In sphenacodontids, an extension of the atlantal centrum reaches the ventral surface of the column and prevents contact between the atlantal and axial intercentra (state 1)(Reisz 1986). Reisz (1980) suggested that this state might also be present in varanopids, as noted by Benson (2012), who scored *Archaeovenator* and *Varanodon* as possessing state (1). In *Archaeovenator*, however, the wedge-shaped axial intercentrum is fused to the ventral margin of the atlantal centrum, preventing the centrum from reaching the ventral surface of the column (Reisz and Dilkes 2003). The examination of *Archaeovenator* (KUVP 12483) also indicates that the atlantal intercentrum is somewhat displaced, but would originally have made contact with the anterior margin of the fused atlantal centrum/axial intercentrum. This is similar to the configuration of these elements in *Ophiacodon* (Reisz 1986 fig. 17A) and *Varanosaurus* (Sumida 1989 fig. 26B), so we score *Archaeovenator* instead as possessing state (0). Laurin (1996) suggested that the condition in *Haptodus* might be similar to that of sphenacodontids, since the axial and atlantal intercentra do not meet ventral to the atlantal centrum (Laurin 1993 fig.14). However, the intercentra are in close proximity and the atlantal centrum lacks the flat ventral margin of more derived sphenacodontians, and is therefore scored as state (0).

DELTRAN: Sphenacodontidae + *Cutleria wilmarthi* (0to1), *Varanodon agilis* (0to1). ACCTRAN: Varanopidae (0to1), Sphenacodontia except *Haptodus* (0to1)

203. Cervical vertebrae, axial neural spine, anteroposterior length of apex: longer than or equal to the centrum (0); shorter than centrum (1); short and spine inclined anterodorsally (2)

From Benson (2012 c.151) modified from Gauthier *et al. (*1988 c.126), Reisz *et al. (*1992 c.68), Berman *et al. (*1995 c.74), Fröbisch et *al. (*2011 c.108) Maddin *et al. (*2008 c.80)

In most terminal taxa, including early varanopids (*Archaeovenator* KUVP 12483), varanodontines (Langston and Reisz 1981), ophiacodontids (Sumida 1989, Reisz 1986) and *Haptodus* (Laurin 1996) the apex of the axial neural spine is anteroposteriorly longer than the axial centrum (state 0). Sphenacodontians (Reisz 1986, Reisz *et al.*1992) have a dorsally tapering neural spine, the apex of which is shorter anteroposteriorly than the centrum (state 1). The additional state of Benson (2012 - state 2) describes the distinctive anterodorsal inclination of the axial neural spine in caseids (Reisz and Fröbisch 2014) and edaphosaurids (Modesto and Reisz 1990). The early araeoscelidian diapsid *Araeoscelis* (Vaughn 1955) is scored as possessing state (1) due to its unusually elongate cervical centra.

Unambiguous: Sphenacodontidae (0to1), Edaphosauridae (0to2), *Araeoscelis* spp (0to1). DELTRAN: *Eocasea martini* (0to2), *Euromycter rutena* + *Ennatosaurus tecton* (0to2). ACCTRAN: Casea broilii (2to0), Caseasauria (0to2)

204. Cervical vertebrae, axial neural spine, dorsoventral height: low, subequal to the centrum height (0); tall, approximately 1.5 times the height of the centrum (1); very tall, many times the centrum height (2)

From Benson (2012 c.152), Spindler *et al. (*2018 c. 106)

Unambiguous: Varanodontinae (0to1), 'protorothyridids' (0to1), *Dimetrodon* spp (1to2), *Ianthasaurus hardestiorum* (0to2), Sphenacodontia (0to1). DELTRAN: *Procolophon trigoniceps* (0to1), *Stereosternum tumidum* (0to1), *Ophiacodon* spp (0to1), *Archaeothyris florensis* (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (1to0), Parareptilia (0to1), *Varanosaurus acutirostris* (1to0), Ophiacodontidae except *Echinerpeton* (0to1)

205. Cervical vertebrae - ribs, slender and tapering at low angle to vertebrae: absent (0); present (1)

Modified from Dilkes (1998 c.77), Müller (2004 c.102), Nesbitt (2011 c.196), Ezcurra *et al. (*2014 c.173), Pritchard *et al. (*2015 c.104), Ezcurra (2016 c.349)

Character state (1) is present in archosauriforms (e.g. *Proterosuchus*)(Nesbitt 2011). It is also present in *Prolacerta* (Gow 1975).

DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1).

206. Cervical vertebrae, centra length: shorter than or subequal to the dorsal centra (0); markedly longer than dorsal centra (1)

From Spindler *et al. (*2018 c.107) modified from Laurin (1993 c.93), Fröbisch et *al. (*2011 c.70), Benson (2012 c.153) modified from Reisz *et al. (*1992 c.70), Modesto (1994 c.25, 1995 c.23), Reisz *et al. (*2010 c.69), Mazierski and Reisz (2010 c.25), Nesbitt (2011 c.181)

State (1) of this character is present in sphenacodontids, and in the varanodontines *Varanops* and *Aerosaurus greenleeorum* (Romer and Price 1940, table 3). However, there is some degree of intraspecific and sexual dimorphism in *Dimetrodon*, and in *Aerosaurus wellesi* the cervical centra are marginally shorter than the mid-dorsals, although this measurement is 'uncorrected for distortion' (Langston and Reisz 1981 table 1). We therefore score both *Dimetrodon* and *Aerosaurus* as [0,1]. There is a conspicuous elongation of the cervical centra relative to the dorsal centra (state 1) in araeoscelidian diapsids (Vaughn 1955, Reisz 1981), and the archosauromorphs *Prolacerta* and *Proterosuchus* (Nesbitt 2011).

Unambiguous: Araeoscelidia (0to1). DELTRAN: Archosauromorpha (0to1), *Secodontosaurus obtusidens* (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1), *Lanthanolania* + Archosauromorpha (0to1), Sphenacodontia except *Haptodus* (0to1)

207. Cervical vertebrae, ventral surface of cervical centra: rounded (0); bearing a low keel or ridge (1), bearing a prominent, transversely narrow, sheet-like keel (2)

Modified from Gauthier *et al. (*1988 c.139), Laurin (1991 H.2), Reisz *et al. (*1992 c.69 in part), Laurin (1993 c.92), deBraga and Rieppel (1997 c.103), Reisz *et al. (*2010 c.70), Nesbitt (2011 c.190), Benson (2012 c.154), Pritchard *et al. (*2015 c.108), Ezcurra (2016 c.327), Spindler *et al. (*2018 c.109)

State (1) of this character is present in *Procolophon* (deBraga 2003), *Haptodus* (Laurin 1993) early varanopids and mycterosaurines (Reisz and Dilkes 2003, Anderson and Reisz 2004, Reisz and Modesto 2007), varanodontines (Maddin *et al. 2*006, Campione and Reisz 2010), ophiacodontids (Romer and Price 1940, Sumida 1989) and captorhinids (deBraga and Rieppel 1997). It is also present in *Orovenator (*Reisz *et al. 2*011), araeoscelidians (Reisz 1981, Vaughn 1955), *Acerosodontosaurus* (Currie 1980) and early archosauromorphs (Ezcurra *et al. 2*014 Appendix S1). In sphenacodontids, the keel is dorsoventrally deeper and sheet-like (state 2) (Reisz 1986). Caseids (Olson 1968) possess a rounded ventral surface of the cervical centra (state 0).

Unambiguous: Sphenacodontidae (1to2), Caseasauria (1to0). DELTRAN: *Cutleria wilmarthi* (1to0). ACCTRAN: Sphenacodontia except *Haptodus* (1to0)

208. Cervical vertebrae, neural arch excavation (lateral to the base of the neural spine): absent (0); present (1)

Modified from Reisz *et al. (*2010 c.71) modified from Reisz and Dilkes (2003 c.47), Ezcurra *et al. (*2014 c.70), Ezcurra (2016 c.337)

Shallow depressions in the dorsolateral of the cervical neural arches (state 1) are present in some mycterosaurines (e.g. *Heleosaurus* and *Mesenosaurus*, Reisz and Modesto 2007; *Mycterosaurus*, Berman and Reisz 1982) and varanodontines (e.g. *Varanops*, Maddin *et al. 2*006). State (1) is also present on the axial neural arch of *Dimetrodon milleri* (MCZ 1365), but is absent in *Secodontosaurus* (MCZ 5203). It can also be found in araeoscelidians (Reisz 1981, Vaughn 1955) and *Proterosuchus* (Ezcurra 2016).

Unambiguous: Mycterosaurinae + Varanodontinae (0to1), *Proterosuchus* spp (0to1), Araeoscelidia (0to1), *Secodontosaurus obtusidens* (1to0), Sphenacodontia except *Haptodus* (0to1)

209. Cervical vertebrae, outline of neural spines in lateral view: sub-rectangular (0); sub-triangular (1)

From Reisz *et al. (*2010 c.72), Ezcurra *et al. (*2014 c.71), Ezcurra (2016 c.339)

In the current taxon list, state (1) is scored as being present in captorhinids (Heaton and Reisz 1980, *Protocaptorhinus* MCZ 1478).

DELTRAN: *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to1). ACCTRAN: Captorhinidae (0to1)

210. Cervical ribs, accessory process on anterolateral surface: absent (0); present (1)

From Laurin (1991 H.4), Rieppel (1999 c.71), Müller (2004 c.48), Reisz *et al. (*2010 c.77), Ezcurra *et al. (*2014 c.76), Pritchard *et al. (*2015 c.105)

Character state (1), an anteriorly projecting acumate process on the anterolateral margin of the cervical ribs, is present in araeoscelidians (Reisz 1981) and archosauromorphs (Ezcurra 2016). It is also present in the mesosaurids *Stereosternum* and Mesosaurus (Modesto 1999, Modesto 2010).

Unambiguous: Mesosauridae (0to1), Araeoscelidia (0to1). DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1)

211. Cervical ribs, proximal heads: some or all holocephalous (single-headed)(0); all dichocephalous (double-headed)(1)

Modified from Laurin (1991 F.4), Reisz *et al. (*2010 c.78), Müller (2004 c.104) Bickelmann *et al. (*2009 c.104), Ezcurra *et al. (*2014 c. 77)

There is some ambiguity in previous discussions of this character and of ch.225 below. In many taxa the region of articular surface of the rib is triangular in shape, and consists of thickened ridges of bone on the dorsal (the tuberculum) and ventral (the capitulum) articular surface, which correspond with the tubercular (upper: diapophysis) and capitular (lower: parapophysis) facets on the vertebra. These thickened areas are often connected by a thin, dorsoventrally oriented lamina or webbing, and together form a continuous contact with the vertebra. Romer and Price (1940:110) noted, 'this may be regarded as a holocephalous condition, but actually the rib is double-headed'. However, Moss (1972:27) notes of *Tseajaia* that the ribs are 'holocephalous, the capitulum and tuberculum being connected by a thin web of bone'. Likewise, Laurin (1993) on the axial rib of the sphenacodontian *Haptodus* noted, ' the axial rib is holocephalous because there is no notch in the web connecting the tuberculum and the capitulum' (Laurin 1993:214). In the neodiapsid *Acerosodontosaurus*, a bridge of bone joins the distinct tubercular and capitular regions, and this condition was also considered as holocephalous by Currie (1980). In a later study on the same specimen, the ribs were described as double-headed, although in the phylogenetic matrix of the same study they were scored as holocephalous (Bickelmann *et al. 2*009). Ezcurra *et al. (*2014) then scored *Acerosodontosaurus* as possessing dichocephalous ribs, based on the comments of Bickelmann *et al. (*2009). To clarify this issue we take the following approach to both cervical and dorsal ribs (partly based on the definition of Müller 2004 c.104):
(i) Where a lamina of bone forms a continuous ridge of uninterrupted contact between the tubercular and capitular regions of the articular surface of the rib, the condition is holocephalous (contra Romer and Price 1940) (state 0). In respect to

the cervical ribs, this occurs in *Gephyrostegus* (Godfrey and Reisz 1991), *Hylonomus* (Carroll 1964), *Limnoscelis* (Williston 1911, Romer 1946, Kennedy 2010), *Ianthasaurus hardestiorum* (Reisz and Berman 1986), *Haptodus* (Laurin 1993), early varanopids and mycterosaurines (e.g. *Archaeovenator*, Reisz and Dilkes 2003; *Heleosaurus*, Botha-Brink and Modesto 2009), *Proterosuchus* (Ezcurra 2016), *Captorhinus aguti* (Fox and Bowman 1966), *Mesosaurus* (Modesto 2010), *Stereosternum* (Modesto 1999), *Deltavjatia*(Tsuji 2013) and *Araeoscelis* (Vaughn 1955). (iii) Where the lamina of bone is proximally notched or interrupted between the tubercular and capitular regions of the articular surface of the rib or there is a clear bifurcation of the capitulum and tuberculum, the condition is dichocephalous (state 1). This condition is present in the cervical ribs of *Seymouria* (White 1939), caseids (Olson 1968) ophiacodontids (e.g. *Ophiacodon MCZ* 1366, Romer and Price 1940), *Dimetrodon* and *Edaphosaurus* (Romer and Price 1940), varanodontines (e.g. *Aerosaurus*, Langston and Reisz 1981; *Varanodon*, Olson 1965), some 'protorothyridids' (e.g. *Coelostegus*, Carroll and Baird 1972; *Paleothyris,* Carroll 1969), *Petrolacosaurus* (Reisz 1981), some captorhinids (e.g. *Thuringothyris*, Müller et *al. 2*006; *Protocaptorhinus*, Clark and Carroll 1973) and procolophonoids (e.g. *Owenetta*, Reisz and Scott 2002; *Procolophon*, deBraga 2003).

Unambiguous: Varanodontinae (0to1), *Claudiosaurus germaini* (0to1), *Haptodus garnettensis* (1to0), *Ianthasaurus hardestiorum* (1to0), 'protorothyridids' except *Hylonomus* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Procolophonoidea (0to1), Protocaptorhinus pricei (0to1), *Thuringothyris mahlendorffae* (0to1), Synapsida (0to1), *Seymouria* spp (0to1). ACCTRAN: *Nyctiphruretus* + Procolophonoidea (0to1), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (1to0), Reptilia except Captorhinidae (1to0), Diadectomorpha (1to0), *Seymouria* spp + Diadectomorpha + Amniota (0to1)

212. Cervicodorsal vertebrae, mammillary processes on posterior cervical and anterior dorsal neural spines: absent (0); present (1)

From Laurin (1991 H.3), Reisz *et al. (*2010 c.76), Ezcurra *et al. (*2014 c.75), Pritchard *et al. (*2015 c.125), Ezcurra (2016 c.320)

The mammillary process is a small lip of dorsolaterally directed bone that is located on the lateral surface of the neural spine close to the dorsal margin (Reisz 1981, Ezcurra 2016). It is present in araeoscelidian diapsids (e.g. *Petrolacosaurus*, Reisz 1981; *Araeoscelis*, Vaughn 1955) and archosauromorphs (Ezcurra 2016). Modesto (2010) notes that mammillary processes are present on the cervical and dorsal vertebrae of *Mesosaurus*. However, the position of these processes, directly dorsal to the postzygopophyses, and their posterodorsal orientation, makes it unlikely that they are homologous with the processes found in diapsids. Therefore, *Mesosaurus* is scored as possessing state (0) here.

Unambiguous: Araeoscelidia (0to1). DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1)

213. Dorsal vertebrae, anteroposterior length of centra: short, subequal to height (0); long, at least 1.5 times as long as high (1)

From Benson (2012 c.155), Ezcurra *et al. (*2014 c.176), Spindler *et al. (*2018 c.108), Ezcurra (2016 c.351, 352)

Unambiguous: *Claudiosaurus germaini* (0to1), *Vaughnictis smithae* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (1to0), *Haptodus garnettensis* (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1), *Protorothyris archeri* (0to1), *Araeoscelis* spp (0to1). DELTRAN: *Mesosaurus tenuidens* (0to1), Captorhinidae except *Euconcordia* (0to1), *Archaeovenator hamiltonensis* (0to1), *Heleosaurus scholtzi* (0to1). ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), Mesosauridae (0to1), Captorhinidae (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1)

214. Dorsal vertebrae, ventral surface of dorsal centra: rounded (0); bearing a low ridge or keel (1); bearing a prominent, transversely narrow, sheet-like keel (2); bearing a ventrally raised platform or keel with longitudinal trough (3)

Modified from Laurin (1991 H.2), Berman *et al. (*1995 c.75), Reisz and Dilkes (2003 c.44), Maddin *et al. (*2006 c.50), Reisz *et al. (*1992 c.71), Reisz *et al. (*2009 c.62), Fröbisch et *al. (*2011 c.109), Reisz and Dilkes (2003 c.44), Reisz *et al. (*2010 c.74) Benson (2012 c.156 state 3), Spindler *et al. (*2018 c.110)

State (3) describes the condition found in some ophiacodontids, including *Ophiacodon* (Romer and Price 1940). It is also present in *Heleosaurus* (Reisz and Modesto 2007) and *Procolophon* (deBraga 2003). State (2) is present in sphenacodontids.

Unambiguous: *Ophiacodon* spp (1to3), Sphenacodontidae (1to2), *Heleosaurus scholtzi* (1to3). DELTRAN: *Proterosuchus* spp (1to0), *Procolophon trigoniceps* (1to3), *Mesosaurus tenuidens* (1to0), *Thuringothyris mahlendorffae* (0to1), Reptilia except Captorhinidae (0to1), *Tseajaia campi* (0to1), *Cutleria wilmarthi* (0to1), *Ianthasaurus hardestiorum* (0to1), Ophiacodontidae (0to1). ACCTRAN: *Nyctiphruretus* + Procolophonoidea (1to3), Parareptilia except Mesosauridae (0to1), Neoreptilia (1to0), Captorhinidae except *Euconcordia* and *Thuringothyris* (1to0), Amniota + Diadectomorpha (0to1), *Limnoscelis paludis* (1to0), *Haptodus garnettensis* (1to0), *Edaphosaurus boanerges* (1to0), Caseasauria (1to0)

215. Dorsal vertebrae, transverse processes in trunk: short, projecting equal with or only slightly beyond the lateral surface of the neural arch (0); moderately long, projecting clearly beyond the lateral surface of the neural arch (1)

Modified from Laurin (1991 F.5), Reisz *et al. (*2010 c.75), Benson (2102 c.158), Ezcurra *et al. (*2014 c.74), Ezcurra (2016 c.358)

The transverse process is moderately long (state 1) in *Seymouria* (White 1939, anterior dorsals only), caseids (e.g., *Casea broilii*, FMNH UC 656; *Ennatosaurus*, Olson 1968), with the exception of *Eocasea* (Reisz and Fröbisch 2014), sphenacodontians (Romer and Price 1940), ophiacodontids (e.g. *Ophiacodon,* Romer and Price 1940 fig. 44; *Archaeothyris*, Reisz 1972 fig. 6c; *Varanosaurus*, Sumida 1989) and archosauromorphs (Ezcurra 2016).

Unambiguous: *Seymouria* spp (0to1), *Ianthasaurus hardestiorum* (1to0), Anthracodromeus hamiltonensis (0to1). DELTRAN: Archosauromorpha (0to1), *Deltavjatia rossicus* (0to1), Caseidae (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Pareiasauria + Nycteroleteridae (0to1), Synapsida (0to1), Eothyrididae (1to0)

216. Dorsal vertebrae, outline of anterior and middle dorsal neural spines in lateral view: sub-triangular (0); sub-rectangular (1); dorsal neural spines are long and thin (2)

Modified from Ezcurra *et al. (*2014 c.179)

Unambiguous: Diapsida (0to1), Synapsida (0to1), *Dimetrodon* spp (1to2), Edaphosauridae (1to2), Anthracodromeus hamiltonensis (0to1). DELTRAN: Parareptilia except Mesosauridae and Bolosauria (1to0). ACCTRAN: Parareptilia (1to0)

217. Dorsal vertebrae, posterior dorsal neural spines, orientation: approximately vertical (0); moderately anterodorsally inclined (1); strongly posterodorsally inclined (2)

Modified from Benson (2012 c.165), Spindler *et al. (*2018 c.112), Ezcurra (2016 c.362 in part)

There is a moderate anterodorsal inclination in the neural spines of *Archaeovenator* (Reisz and Dilkes 2003), *Mycterosaurus* (Berman and Reisz 1982 fig.9B) and most varanodontines (e.g. *Varanodon*, Williston 1911 plate 2). Edaphosaurids are scored as possessing state (2) (Modesto and Reisz 1990, Romer and Price 1940).

Unambiguous: Edaphosauridae (0to2). DELTRAN: Varanopidae except

Ascendonanus (0to1). ACCTRAN: Varanopidae (0to1)

218. Dorsal vertebrae, anterodorsally inclined posterior dorsal neural spines: posteriormost one or two (0); several posterior dorsal neural spines (1); inapplicable, anterodorsally inclined dorsal neural spines are absent (-)

Modified from Benson (2012 c.165)

This character describes the variation between groups in the number of anterodorsally inclined posterior dorsal neural spines (ch.217 state 1). Mycterosaurines are scored as state (0), and varanodontines as state (1), where the condition can be observed.

DELTRAN: Varanodontinae except *Aerosaurus wellesi* (0to1). ACCTRAN: Varanodontinae (0to1)

219. Dorsal vertebrae, neural spines, height: short, approximately 1.5 times centrum height or lower (0); intermediate, 2-3 times centrum height (1); very tall (2).

From Benson (2012 c.164) modified from Reisz *et al. (*1992 c73, 74), Laurin (1993 c.82), Berman *et al. (*1995 c.77), Modesto (1995 c.24), Reisz *et al. (*1998 c.31), Maddin *et al. (*2006 c.52), Reisz *et al. (*2009 c.61), Mazierski and Reisz (2010 c.26, 27), Fröbisch et *al. (*2011 c.64) Ezcurra *et al. (*2014 c.72), Spindler *et al. (*2018 c.111)

The tall dorsal neural spines of sphenacodontids and edaphosaurids are scored as state (2) (Romer and Price 1940). In *Haptodus* (ROM 29872), *Ophiacodon* (MCZ 1366), *Mycterosaurus* and varanodontines (FMNH UR 986, Reisz and Laurin 2004, Langston and Reisz 1981), *Procolophon* (deBraga 2003) and *Mesosaurus* (Modesto 2010) the dorsal neural spines are at least twice the height of the centrum (state 1). This differs from the condition in most other early amniotes (e.g. caseasaurs, other mycterosaurines, 'protorothyridids', araeoscelidians and neodiapsids) in which the dorsal neural spines are short (state 0).

Unambiguous: *Procolophon trigoniceps* (0to1), *Ophiacodon* spp (0to1), Sphenacodontidae (1to2), Edaphosauridae (1to2). DELTRAN: Varanodontinae (0to1), *Mesosaurus tenuidens* (0to1), Sphenacodontia (0to1), *Mycterosaurus longiceps* (0to1). ACCTRAN: Mycterosaurinae + Varanodontinae (0to1), Mesosauridae (0to1), Sphenacodontia + Edaphosauridae (0to1), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (1to0)

220. Dorsal vertebrae, neural spines, lateral tubercles: absent (0); present (1)

From Reisz *et al. (*1992 c.77), modified from Modesto (1994 c.29, 1995 c.26), Mazierski and Reisz (2010 c.29), Benson (2012 c.169)

State (1) is a unique synapomorphy of edaphosaurids (Reisz 1986, Reisz and Berman 1986)

Unambiguous: Edaphosauridae (0to1).

221. Dorsal vertebrae, neural spines morphology: consistent along column (0); alternating (1)

From Benson (2012 c.167)

Alternating height or morphology of the dorsal neural spine is present (state 1) in *Varanosaurus* (Sumida 1989), *Seymouria*, diadectomorphs (e.g. *Limnoscelis*, *Tseajaia*), araeoscelidians (e.g. *Petrolacosaurus* and *Araeoscelis*) and derived captorhinids (e.g. *Captorhinus* and *Protocaptorhinus*, Sumida 1990). Gow (1975) also notes the dorsal neural spines of the archosauromorph *Prolacerta* show a slight but distinct alternation in length (state 1).

Unambiguous: *Prolacerta broomi* (0to1), Araeoscelidia (0to1), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), Amniota (1to0), *Varanosaurus acutirostris* (0to1)

222. Dorsal vertebrae, anterior centrodiapophyseal lamina: absent (0); present (1)

From Brinkman and Eberth (1983 c.17), Ezcurra *et al. (*2014 c.180), Benson (2012 c. 158 in part), Ezcurra (2016 c.315)

In the dorsal vertebrae of several terminal taxa a conspicuous lamina extends anteroventrally from the base of the transverse process to the anterodorsal corner of the centrum. This morphology is very similar to the anterior centrodiapophyseal lamina used to describe the vertebrae of early archosauromorphs (Ezcurra 2016) and saurischian dinosaurs (Wilson 1999), and this term is adopted herein. An anterior centrodiapophyseal lamina is present in derived ophiacodontids (Brinkman and Eberth 1983, Sumida 1989, Romer and Price 1940 fig.44F), and the archosauromorphs *Prolacerta* and *Proterosuchus* (Ezcurra 2016). In *Petrolacosaurus* a thin ridge runs anteroventrally from the transverse process to the anterior centrosphene in both dorsal and cervical vertebrae (Reisz 1981). Ezcurra *et al. (*2014) scored this condition as an anterior centrodiapophyseal lamina, although later noting its absence in *Petrolacosaurus* (Ezcurra 2016 c.315: 199). Herein we score this as state (1).

Unambiguous: Ophiacodontidae (0to1). DELTRAN: Varanopidae except

Ascendonanus, *Orovenator* and *Archaeovenator* (0to1), Neodiapsida except *Claudiosaurus* (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Parareptilia (1to0), Diapsida (0to1), *Araeoscelis* spp (1to0)

223. Dorsal vertebrae, dorsolateral surface: flat or weakly concave (0); swollen and convex (1); excavated by a depression lateral to the base of the neural spine (2)

Modified from Brinkman and Eberth (1983 c.16), Reisz *et al. (*1992 c.79), Laurin (1993 c.84), Modesto (1994 c.30, 1995 c.28), Berman *et al. (*1995 c.79), Laurin and Reisz (1995 c.86), Dilkes (1998 c.84), Reisz and Dilkes (2003 c.47), Müller (2004 c.103 in part), Maddin *et al. (*2006 c.51), Maddin *et al. (*2008 c.74), Reisz *et al. (*2009 c.60), Mazierski and Reisz (2010 c.31), Fröbisch et *al. (*2011 c.66), Benson (2012 c.163), Ezcurra *et al. (*2014 c.184), Modesto *et al. (*2015 c.127), Ezcurra (2016 c.361), Spindler *et al. (*2018 c.115)

Among out-group taxa, the dorsal neural arches are swollen (state 1) in *Seymouria* and diadectomorphs (Sumida 1990). They are flat (state 0) in most early amniotes, including caseasaurs (Sumida *et al. 2*014, Brocklehurst *et al. 2*016, Reisz and Fröbisch 2014), ophiacodontids (Romer and Price 1940), with the exception of *Varanosaurus*, early varanopids (Reisz and Dilkes 2003, Spindler *et al. 2*018), 'protorothyridids' (Carroll 1964, 1969), early neodiapsids (Currie 1980) and *Milleretta* (Gow 1972). The neural arches are swollen and convex in *Varanosaurus* (Sumida 1990), derived captorhinids (Heaton and Reisz 1986, Sumida 1990) and many early and derived parareptiles (e.g. *Mesosaurus*, Modesto 2010; bolosaurids, Berman *et al. 2*000, with the exception of *Erpetonyx,* Modesto *et al. 2*015;*Macroleter*, Tsuji 2006 and procolophonoids, deBraga 2003,Reisz and Scott 2002). Lateral excavations are present in sphenacodontians (Romer and Price 1940, Currie 1977), *Ianthasaurus* (Mazierski and Reisz 2010), mycterosaurines (Reisz *et al. 2*010, Berman and Reisz 1982) and varanodontines (Reisz and Laurin 2004). Araeoscelidians, *Prolacerta* and *Proterosuchus* are also scored as state 1 (Reisz 1981, Ezcurra 2016). Modesto *et al. (*2015) noted paired excavations in the dorsolateral surface of the neural arch in in the *Erpetonyx*.

Unambiguous: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to2), Erpetonyx arsenaultorum (1to2), *Milleretta rubidgei* (1to0), Parareptilia (0to1), Araeoscelidia (0to2), Amniota (1to0), *Varanosaurus acutirostris* (0to1). DELTRAN: Archosauromorpha (0to2), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* + Protocaptorhinus (0to1), *Ianthasaurus hardestiorum* (0to2), Sphenacodontia (0to2). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to2), Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), *Edaphosaurus boanerges* (2to0), Sphenacodontia + Edaphosauridae (0to2)

224. Dorsal vertebrae, postzygapophyses: widely spaced (0); contact on midline (1).

From Benson (2012 c.161), Spindler *et al. (*2018 c.118)

Unambiguous: *Ophiacodon* spp (0to1), *Edaphosaurus boanerges* (0to1), *Varanodon agilis* + *Watongia meieri* (0to1). DELTRAN: *Prolacerta broomi* (0to1), Sphenacodontidae (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Sphenacodontia except *Haptodus* (0to1)

225. Dorsal vertebrae, trunk ribs: mostly dichocephalous (double-headed)(0); mostly holocephalous (single-headed)(1)

From Laurin (1991 D.3), Dilkes (1998 c.86), Müller (2004 c.104), Reisz *et al. (*2010 c.79), Ezcurra *et al. (*2014 c.78), Spindler *et al. (*2018 c.119)

Refer to ch.211 above for a discussion on the morphology of single- and double-headed ribs. In the current taxon list a single-headed (holocephalous) rib attachment to the dorsal vertebrae (state 1) is present in diadectomorphs (Moss 1972, Romer 1946), diapsids (Currie 1980, a synapomorphy in Laurin 1991, Ezcurra 2016) and most parareptiles (Gow 1997, deBraga 2003, Modesto 2010, Modesto *et al. 2*015). The articular surfaces of the pre-sacral trunk ribs in *Heleosaurus* are triangular in outline and holocephalous (State 1) (Botha-Brink and Modesto 2009). This is similar to the condition found in *Mycterosaurus* (Berman and Reisz 1982), *Archaeovenator* (Reisz and Dilkes 2003) and *Ascendonanus* (Spindler *et al. 2*018). The dichocephalous condition (state 0) is present in *Seymouria* (White 1939), varanodontines (Pelletier 2014), *Apsisaurus* (Laurin 1991), ophiacodontids, caseids, sphenacodontians and edaphosaurids (Romer and Price 1940, Laurin 1993, Mazierski and Reisz 2010), *Araeoscelis* (Vaughn 1955), *Petrolacosaurus* (Reisz 1981), captorhinids (e.g. *Thuringothyris*, Müller *et al. 2*006; *Captorhinus aguti*, Fox and Bowman 1966 and *Captorhinus laticeps,* Heaton and Reisz 1980) and *Owenetta* (Reisz and Scott 2002).

Unambiguous: Varanopidae + Neoreptilia (0to1), Diadectomorpha (0to1). DELTRAN: Varanodontinae (1to0), Apsisaurus witteri (1to0), *Owenetta kitchingorum* (1to0). ACCTRAN: Mycterosaurinae (0to1), Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to0), Owenettidae (1to0)

226. Dorsal vertebrae, trunk ribs, curvature: curved proximally, only weakly curved distally (0); strongly arched proximally, curved throughout length enclosing expanded, 'barrel- shaped' trunk (1)

From Benson (2012 c.170) modified from Modesto (1994 c.32, 1995 c.34), Maddin *et al. (*2008 c.79), Mazierski and Reisz (2010 c.37)

Caseids and *Edaphosaurus* share the derived state, which is an adaptation for high-fibre herbivory. The trunk ribs in *Procolophon* are only gently curved (state 0)(deBraga 2003).

Unambiguous: *Edaphosaurus boanerges* (0to1), Caseidae (0to1).

227. Osteoderms: absent (0); present dorsally on trunk (1)

From Botha-Brink and Modesto (2009 c.62), Nesbitt 2011 (c.401), Ezcurra (2016 c.588), Spindler *et al. (*2018 c.1)

Osteoderms are present (state 1) in *Heleosaurus* (Reisz and Modesto 2007), *Elliotsmithia* (Reisz *et al.*1998) and *Youngina* (Gow 1975). They are also present in the pareiasaur *Deltavjatia rossicus* (Tsuji 2013).

Unambiguous: *Youngina capensis* (0to1), *Deltavjatia rossicus* (0to1). DELTRAN: *Heleosaurus scholtzi* (0to1), *Elliotsmithia* longiceps (0to1). ACCTRAN: Mycterosaurinae (0to1), *Mesenosaurus romeri* (1to0)

228. Sacral vertebrae, morphology of first sacral rib: greatly enlarged in comparison with the second sacral rib (0); subequal to or only slightly larger than the second sacral rib (1).

Modified from Berman *et al. (*1995 c.76), reversed from Maddin *et al. (*2008 c.76, 77) modified from Reisz and Dilkes (2003 c.48), Maddin *et al. (*2006 c.53), Reisz *et al. (*2009 c.63), Benson (2012 c.173), Ezcurra 2016 c.372), Spindler *et al. (*2018 c.122)

Unambiguous: Neoreptilia (0to1), Caseidae (0to1), Sphenacodontia + Edaphosauridae (0to1), *Paleothyris acadiana* + *Protorothyris archeri* (0to1). DELTRAN: *Eudibamus cursoris* (1to0), *Archaeovenator hamiltonensis* (0to1). ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Eudibamus cursoris* + *Belebey vegrandis* (1to0)

229. Sacral vertebrae, second sacral rib: not bifurcate (0); bifurcate (1)

From Dilkes (1998 c.87), Müller (2004: 105), Nesbitt (2011 c. 203), Ezcurra *et al. (*2014 c.187), Pritchard *et al. (*2015 c.131), Ezcurra (2016 c.373)

State (1) of this character is present in a few early archosauromorphs e.g. *Prolacerta* and *Proterosuchus* (Dilkes 1998, Nesbitt 2011). The first, rather than the second, sacral rib in *Aerosaurus* is 'Y' shaped (Langston and Reisz 1981), and is therefore scored here as state (0).

DELTRAN: Archosauromorpha (0to1). ACCTRAN: *Lanthanolania* +

Archosauromorpha (0to1).

230. Sacral vertebrae, count: two or fewer (0); three or greater (1)

From Reisz *et al. (*1992 c.72), Laurin (1993 c.94), Laurin and Reisz (1995 c.88), Reisz and Dilkes (2003 c.48), Maddin *et al. (*2006 c.53, 2008 c.75), Reisz *et al. (*2009 c.63), Tsuji *et al. (*2012 c. 96), Benson (2012 c.172), Modesto *et al. (*2015 c.129), Spindler *et al. (*2018 c.121).

Three or more sacral vertebrae (state 1) are present in most caseids (e.g. *Casea*, Olson 1968), most edaphosaurids (e.g. *Edaphosaurus*, Romer and Price 1940) and in sphenacodontians (Romer and Price 1940, Currie 1979). LeBlanc and Reisz (2014) posited that state (1) arose independently within each of these groups, since early members possess only two sacral vertebrae e.g. *Eocasea* (Reisz and Fröbisch 2014), and *Ianthasaurus* (LeBlanc and Reisz 2014). Three sacral vertebrae are also present in non-lanthanosuchoid ankyramorphs and the early bolosaurian *Erpetonyx* (Modesto *et al. 2*015), as well as the varanodontine *Aerosaurus* (Langston and Reisz 1981). There are two sacral vertebrae (state 0) in most out-group taxa (e.g. *Seymouria*, White 1939; *Limnoscelis*, Kennedy 2010; *Tseajaia*, Moss 1972). Two sacral vertebrae are present in 'protorothyridids' (e.g. *Paleothyris,* Carroll 1969), araeoscelidians and neodiapsids (e.g. *Petrolacosaurus*, Reisz 1981; *Youngina* and *Prolacerta*, Gow 1975), captorhinids (e.g. *Captorhinus aguti*, Fox and Bowman 1966), *Archaeovenator* (Reisz and Dilkes 2003) and mycterosaurines, the *Varanodon* (FMNH UR 986), ophiacodontids (Romer and Price 1940 fig.45A, Reisz 1972), and the parareptiles *Mesosaurus* (Modesto 2010) and *Milleretta* (Gow 1972).

Unambiguous: Erpetonyx arsenaultorum (0to1), *Aerosaurus wellesi* (0to1).DELTRAN: Ankyramorpha except Lanthanosuchoidea (0to1), Casea broilii (0to1), *Edaphosaurus boanerges* (0to1), Sphenacodontia (0to1). ACCTRAN: Ankyramorpha (0to1), Caseidae (0to1), *Ianthasaurus hardestiorum* (1to0), Sphenacodontia + Edaphosauridae (0to1)

231. Caudal vertebrae, anterior caudal neural spine height: moderately tall with height/length between >1.0 and <2.0 (0); low with height/length <1.0 (1); tall with height/length >2.0 and <3.0 (2); very tall with height/length >3.0 (3)

From Dilkes (1998 c.88), Müller (2004 c.106), Ezcurra *et al. (*2014 c.189), Ezcurra (2016 c.379)

Unambiguous: *Limnoscelis paludis* (1to2), *Varanosaurus acutirostris* (3to1), *Haptodus garnettensis* (3to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to3).DELTRAN: *Youngina capensis* (0to1), *Tseajaia campi* (0to1), Caseasauria (0to1), *Varanodon brevirostris* (0to2). ACCTRAN: Mycterosaurinae +

Varanodontinae (0to2), *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), Reptilia (1to0), Amniota + Diadectomorpha (0to1)

232. Caudal vertebrae, chevrons, distal width of haemal spine: equivalent to proximal width (0); tapering (1); wider than proximal width (2)

From Dilkes 1998 c.91), Müller (2004 c.108), Ezcurra *et al. (*2014 c.192)

Unambiguous: Reptilia (0to1). DELTRAN: Neodiapsida except *Claudiosaurus* (1to2), *Edaphosaurus boanerges* (0to1), *Archaeovenator hamiltonensis* (1to0). ACCTRAN: Neodiapsida (1to2), Varanopidae (1to0), Edaphosauridae (0to1)

233. Clavicle, orientation of long axis of ventromedial plate relative to shaft: highly obtuse angle (0); almost perpendicular (1)

From Benson (2012 c.188)

Unambiguous: *Seymouria* spp (0to1), Sphenacodontia + Edaphosauridae (0to1). DELTRAN: *Youngina capensis* (0to1), 'protorothyridids' (0to1), *Captorhinus aguti* (0to1). ACCTRAN: Neodiapsida (0to1), Diapsida (1to0), Reptilia (0to1)

234. Clavicle, anteroposterior width of ventromedial plate: narrow, less than three times the width of the midpoint of the dorsal shaft (0); narrow, but with a distinct anterior process of the ventromedial plate (1); intermediate, equal to or more than 3 times the width of the midpoint of the dorsal shaft (2), deep, at least 4 times the width of the midpoint of the dorsal shaft (3)

Modified from Benson (2012 c.187) modified from Berman *et al. (*1995 c.83), Laurin and Reisz (1995 c.96), Maddin *et al. (*2006 c.54, 2008 c.82), Reisz *et al. (*2009 c.65), Spindler *et al. (*2018 c.123)

In previous studies the description of the anteroposterior width of the ventromedial plate has been a qualitative (narrow, intermediate, deep) assessment. Here we introduce a quantitative parameter to the character based on the width of the dorsal shaft at the midpoint. In the out-group taxon *Gephyrostegus*, the ventromedial plate is narrow (state 0) (Klembara *et al. 2*014), and this is probably the plesiomorphic state for amniotes (contra Reisz 1986) as this is condition is also present in *Tseajaia* (Moss 1972), *Oedaleops* (Sumida *et al. 2*014), ophiacodontids (e.g. *Ophiacodon,* MCZ 2934), early varanopids (*Archaeovenator* KUVP 12483, Spindler *et al. 2*018) and ‘protorothyridids’ (Carroll 1964, Carroll and Baird 1972), with the exception of *Protorothyris* (see below). The intermediate state (2) is present in *Seymouria* (White 1939), *Petrolacosaurus* (KUVP 9958) and the varanodontines *Aerosaurus* and *Varanops* (Pelletier 2014, MCZ 1926). A deep width of the ventromedial plate (state 3) is present in sphenacodontians (e.g. *Dimetrodon* (MCZ 1365) and edaphosaurids (e.g. *Edaphosaurus*, MCZ 4316) as noted by Reisz (1986). Benson (2012) introduced a new state to account for an additional anterior process on the ventromedial plate in *Captorhinus* and *Protorothyris*. A distinctive anterior process is present in *Captorhinus aguti* (OMNH 15003) and *Limnoscelis* (Romer 1946)(state 1). However, it is absent in *Protorothyris archeri* (MCZ 1532, MCZ 2148), which is scored for the intermediate state (2) herein.

Unambiguous: *Seymouria* spp (0to2), *Limnoscelis paludis* (0to1), *Protorothyris archeri* (0to2). DELTRAN: *Mesosaurus tenuidens* (0to2), *Captorhinus aguti* (0to1), *Dimetrodon* spp (0to3), *Edaphosaurus boanerges* (0to3), *Petrolacosaurus kansensis* (0to2), *Varanops brevirostris* (0to2), *Aerosaurus wellesi* (0to2). ACCTRAN: Varanodontinae (0to2), Mesosauridae (0to2), Araeoscelidia (0to2), Captorhinidae (0to1), Sphenacodontidae (0to3), Edaphosauridae (0to3), *Varanodon agilis* + *Watongia meieri* (2to0)

235. Interclavicle, median notch on anterior margin: absent (0); present (1)

From Ezcurra *et al. (*2014 c.195) modified from Dilkes (1998 c.97), Müller (2004 c.111), Pritchard *et al. (*2015 c.134), Ezcurra (2016 c.407)

A median notch is present in *Limnoscelis* (Williston 1911 fig.11A), *Archaeovenator* (KUVP 12483), *Paleothyris*(pers. obs. μCT data from MCZ 3481), *Petrolacosaurus* (Reisz 1981) and archosauromorphs (Ezcurra 2016).

Unambiguous: *Paleothyris acadiana* (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Archosauromorpha (0to1), *Limnoscelis paludis* (0to1), *Archaeovenator hamiltonensis* (0to1). ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), *Lanthanolania* + Archosauromorpha (0to1), Diadectomorpha (0to1)

236. Interclavicle, posterior stem: little change in width along entire length or attenuates posteriorly (0); expansion present (1)

Modified from (Dilkes 1998 c.98), Müller (2004 c.112), Ezcurra *et al. (*2014 c.196), Pritchard *et al. (*2015 c.144), Ezcurra (2016 c.411)

Unambiguous: *Seymouria* spp (0to1), *Tseajaia campi* (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Prolacerta broomi* (0to1), *Procolophon trigoniceps* (0to1), Mesosauridae (0to1), *Varanops brevirostris* (0to1). ACCTRAN: *Proterosuchus* spp (1to0), *Milleretta rubidgei* (1to0), Neoreptilia (0to1), Varanodontinae except *Aerosaurus wellesi* (0to1)

237. Interclavicle, shape of interclavicular head in ventral view: paddle-shaped (0); diamond or spade shaped with anteroposterior length sub-equal to or greater than the transverse width (1); lateral processes or wings present,

with transverse width approximately two times greater than anteroposterior length of interclavicular head (2)

Modified from (Laurin 1991 J.6), Berman *et al. (*1995 c.8), Laurin and Reisz (1995 c.92), Benson (2012 c.190), Spindler *et al. (*c.125, 126)

There is some degree of variation in the morphology of the interclavicular head among early amniotes. Herein we identify three principle morphologies associated with the current taxon list: state (1), a broad, paddle-shape with a smoothly convex lateral margin (e.g. *Seymouria*, White 1939), state (2), anteroposterior length sub-equal to or greater than the transverse width, with no clearly defined lateral wings, and a diamond or spade-like outline (e.g. *Dimetrodon* sp. MCZ 4443; *Ophiacodon mirus*, MCZ 294; *Edaphosaurus boanerges*, MCZ 4315; *Varanops brevirostris*, MCZ 1926), state (3), distinct lateral processes, where the transverse width is around double that of the anteroposterior length (e.g. *Oedaleops*, Sumida *et al. 2*014; *Archaeovenator*, KUVP 12483; *Ascendonanus*, Spindler *et al. 2*018; *Ophiacodon uniformis*, Romer and Price 1940 fig.21; *Petrolacosaurus*, Reisz 1981; *Prolacerta* and *Proterosuchus* (Ezcurra 2016 fig.38). For those taxa possessing distinct lateral wings there is a further subdivision in the presence or absence of an anterior process. This distinction is the subject of ch. 238 below. State (0) is scored only for *Seymouria*, and as such is parsimony uninformative, but is maintained for information purposes.

Unambiguous: *Stereosternum tumidum* (2to1), Amniota + Diadectomorpha (0to2). DELTRAN: *Dimetrodon* spp (2to1), *Edaphosaurus boanerges* (2to1), *Varanops brevirostris* (2to1). ACCTRAN: Sphenacodontidae + *Cutleria wilmarthi* (2to1), Edaphosauridae (2to1), Varanodontinae except *Aerosaurus wellesi* (2to1)

238. Interclavicle, if lateral processes or wings are present, an anterior process extends between the clavicles: absent, or reduced to a small nub/mild convexity (0); present (1); inapplicable, lateral wings are absent (-)

Modified from deBraga and Reisz (1995 c.115), Rieppel (1999 c.82), Müller (2004 c.55), Reisz *et al. (*2010 c.82), Ezcurra *et al. (*2014 c.81) Spindler *et al. (*2018 c.124)

State (1) of this character describes the anterior process that partially or fully separates the medial margin of the ventral plate of the clavicles in those taxa with mediolaterally broad lateral processes (ch.237 state 2). It is present in early varanopids(e.g. *Archaeovenator*, Reisz and Dilkes 2003; *Pyozia*, Anderson and Reisz 2004 and *Ascendonanus*, Spindler *et al. 2*018 fig.18B), araeoscelidians (e.g. *Petrolacosaurus*, Reisz 1981), *Protorothyris archeri* (MCZ 1532, Clark and Carroll 1973) and some captorhinids (e.g. *Thuringothyris*, Müller et *al. 2*006). It is absent (state 0) in all ankyramorph parareptiles, in which the mediolaterally broad lateral processes form a 'T-shaped' interclavicle with the posterior stem (Modesto *et al. 2*015 c.134 state 1). State (0) is also scored for caseasaurs (e.g. *Oedaleops*, Sumida *et* *al.* 2014; *Euromycter*, Sigogneau-Russell and Russell 1974), the varanodontine *Aerosaurus* (Langston and Reisz 1981) and the some neodiapsids (e.g. *Youngina* and *Prolacerta*, Gow 1975 and *Proterosuchus*, Ezcurra 2016).

Unambiguous: *Milleretta rubidgei* (0to1), *Paleothyris acadiana* (1to0). DELTRAN: Neodiapsida except *Claudiosaurus* (1to0), Parareptilia (1to0), *Captorhinus aguti* (1to0), Reptilia (0to1), *Ophiacodon* spp (0to1), Sphenacodontia (0to1), *Aerosaurus wellesi* (1to0). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to0), *Claudiosaurus germaini* (0to1), Neoreptilia (1to0), *Captorhinus aguti* + *Captorhinus laticeps* + *Labidosaurikos* + *Labidosaurus* (1to0), Amniota (0to1), *Echinerpeton intermedium* (1to0), Caseasauria (1to0)

239. Scapula, supraglenoid foramen: present (0); absent (1)

From Laurin and Reisz (1995 c.97), Reisz *et al. (*1998 c.29), Reisz and Dilkes (2003 c.29), Reisz and Laurin (2004 c.54), Maddin *et al. (*2006 c.59, 2008 c.84), Reisz *et al. (*2010 c.87), Fröbisch et *al. (*2011 c.112), Ezcurra *et al. (*2014 c.86), Benson (2012 c.179), Modesto *et al. (*2015 c.139), Ezcurra (2016 c.393 polarity reversed), Spindler *et al. (*2018 c.128)

The supraglenoid foramen is located on the posterolateral or posterior surface of the scapula, immediately dorsal to the glenoid. The absence of the supraglenoid foramen is hypothesised to be a derived condition that evolved independently in several lineages of early amniotes (Laurin and Reisz 1995). The foramen is absent in caseasaurs (e.g. *Oedaleops*, Sumida *et al. 2*014 and *Casea*, Williston 1911), neodiapsids (e.g. *Youngina*, BP/1/3859; *Prolacerta*, Gow 1975 and *Proterosuchus*, Ezcurra 2016), parareptiles (e.g. *Mesosaurus*, Modesto 2010 and *Procolophon*, BP/1/692) and early varanopids and mycterosaurines (e.g. *Archaeovenator*, Reisz and Dilkes 2003; *Heleosaurus*, Reisz and Modesto 2007, Botha-Brink and Modesto 2009 and *Mycterosaurus*, Berman and Reisz 1982). Pelletier (2014) stated that a supraglenoid foramen is present in the mycterosaurine *Pyozia*. However, the foramen is 'not evident' in the fragmented scapulocoracoid (Anderson and Reisz 2004:176). Spindler *et al. (*2018) suggested that the foramen is present in *Apsisaurus*. Close examination of the scapula of this taxon has determined that the foramen is absent (MCZ 1474). The foramen-like feature appearing in the illustration of Laurin (1991 fig.7D) in fact is an irregularly shaped discolouration of the bone surface. Consequently, the condition in *Apsisaurus* is scored as (1) herein. The condition in varanodontines is uncertain. Campione and Reisz (2010 fig.10A) noted the presence of a supraglenoid foramen in *Varanops brevirostris*, which is absent in other scapulae assigned to this taxon (MCZ 1926). We therefore score *Varanops* as [0,1] for uncertainty. The supraglenoid foramen is present (state 0) in *Aerosaurus* (Langston and Reisz 1981). The foramen is also scored as present in the parareptile *Nyctiphruretus* (Müller and Tsuji 2007 c.104).

Unambiguous: *Nyctiphruretus acudens* (1to0), Varanopidae + Neoreptilia (0to1), Caseasauria (0to1). DELTRAN: *Aerosaurus wellesi* (1to0). ACCTRAN: Varanodontinae (1to0)

240. Scapula, supraglenoid foramen, location: posterior to the apex of the supraglenoid buttress (0); located on or anterior to the apex of the buttress (1); inapplicable, supraglenoid foramen absent (-)

Modified from Benson (2012 c.180) modified from Reisz *et al. (*1992 c.82), Fröbisch et *al. (*2011 c.112) Spindler *et al. (*2018 c.129)

Character state (0) is present in out-group taxa (e.g. *Seymouria*, White 1939 fig.17A; *Tseajaia*, Moss 197 fig.8A). The supraglenoid foramen is located anterior to the apex of the glenoid buttress (state 1) in sphenacodontians (Romer and Price 1940, *Dimetrodon milleri* MCZ 1365, *Haptodus garnettensis* ROM 43605), 'protorothyridids' (*Paleothyris acadiana* MCZ 3485, Carroll 1969, *Protorothyris* MCZ 2148) araeoscelidians (Reisz 1981, Vaughn 1955) and varanodontines (Langston and Reisz 1981, Campione and Reisz 2010).

Unambiguous: Reptilia except Captorhinidae (0to1), Sphenacodontia (0to1)

241. Scapula, anterior margin: straight or slightly concave, at least dorsally (0); convex along entire length (1)

From deBraga and Reisz (1995 c.27), Reisz *et al. (*2010 c.86), Nesbitt (2011 c.217), Ezcurra *et al. (*2014 c.85), Spindler *et al. (*2018 c.131)

State (1) of this character was introduced by deBraga and Reisz (1995) to describe the broadly convex anterior margin of the scapula in araeoscelidian diapsids (e.g. *Petrolacosaurus*, Reisz 1981 and *Araeoscelis*, Vaughn 1955). State (1) is also convergently present in the eothyridid *Oedaleops* (Sumida *et al. 2*014 fig. 2.5b) and the mesosaurids *Mesosaurus* (Modesto 2010) and *Stereosternum* (Modesto 1999).

Unambiguous: Mesosauridae (0to1), Araeoscelidia (0to1). DELTRAN: *Oedaleops campi* (0to1). ACCTRAN: Eothyrididae (0to1)

242. Scapula, scapulocoracoid notch on anterior margin on scapula/coracoid contact: absent (0); present (1)

From Laurin (1993 c.100), Fröbisch et *al. (*2011 c.76), Benson (2012 c.183), Spindler *et al. (*2018 c.132)

A notch is present on the anterior margin of the scapulocoracoid (state 1) in *Youngina* (Gow 1975), *Prolacerta* (BP/1/2675), *Stereosternum* (Modesto 1999) and

Mesosaurus (Modesto 2010). As noted by Benson (2012 c.183) it is also found in varanodontines, *Ophiacodon and Haptodus*.

Unambiguous: Varanodontinae (0to1), *Proterosuchus* spp (1to0), Neoreptilia (0to1), *Haptodus garnettensis* (0to1). DELTRAN: *Ophiacodon* spp (0to1). ACCTRAN: Ophiacodontidae (0to1)

243. Scapula, 'acromion' process: absent (0); present on the anterior surface of the scapula (1)

From Laurin and Reisz (1995 c.99), deBraga and Rieppel (1997 c.118), Tsuji (2013 c68)

An 'acromion-like' anterolaterally-facing spur is located at the base of the scapula blade of *Deltavjatia rossicus* (Tsuji 2013). A similar process is featured in *Emeroleter levis* (Tsuji *et al.* 2012)

Unambiguous: *Emeroleter levis* + *Deltavjatia rossicus* (0to1)

244. Coracoids, number: one (0); two (1)

From Gauthier *et al. (*1988 c.148), Laurin and Reisz (1995 c.95), Maddin *et al. (*2008 c.85), Benson (2012 c.184), Spindler *et al. (*2018 c.133)

The stem-group amniotes *Seymouria* and diadectomorphs have a single coracoid (state 0)(White 1939, Moss 1972, Kennedy 2010). However, most early amniotes have instead two ossifications of the coracoid (state 1)(e.g. caseasaurs, Williston 1911; sphenacodontians, Romer and Price 1940; ophiacodontids, Watson 1914; edaphosaurids, Romer and Price 1940; the varanodontine *Varanops*, Campione and Reisz 2010; the 'protorothyridid' *Cephalerpeton*, Carroll and Baird 1972; the araeoscelidian diapsids *Petrolacosaurus* and *Araeoscelis*, Reisz 1981, Vaughn 1955; the captorhinid *Captorhinus aguti*, Fox and Bowman 1966 and the procolophonid *Procolophon*, deBraga 2003). In many taxa the anterior and posterior ossifications of the coracoid fuse in mature specimens and the suture between them is lost. For example, immature specimens of *Petrolacosaurus* show post-mortem separation of the anterior and posterior coracoids (Reisz 1981), although there are no sutures separating the coracoids in adult specimens of *Petrolacosaurus*. In some 'protorothyridids' there is no trace of a suture between the two coracoid elements (e.g. *Paleothyris,* Carroll 1969 and *Protorothyris*, Clark and Carroll 1973). The condition in early varanopids and mycterosaurines requires further clarification. The right scapulocoracoid of *Archaeovenator* (KUVP 12483) is fully exposed on the medial surface and, despite some mediolateral compression, is undamaged. There is no visible suture between the scapula and coracoid (Reisz and Dilkes 2003), and neither does there appear to be any suture separating the anterior and posterior areas of the coracoid, making it impossible to determine confidently how many coracoids were present. Equally, in *Mycterosaurus* there is no evidence of a suture between the coracoid elements, although a small ridge probably traces the line of the suture between the scapula and anterior region of the coracoid (Berman and Reisz 1982). Consequently we score these taxa as (?). A single coracoid is present in neodiapsids (Carroll 1981, Smith and Evans 1996) and the parareptiles *Mesosaurus* (Modesto 2010) and *Milleretta* (Gow 1972)

Unambiguous: Neoreptilia (1to0), Amniota (0to1). DELTRAN: Ankyramorpha except Lanthanosuchoidea (0to1). ACCTRAN: Ankyramorpha (0to1)

245. Coracoid, triceps process: absent or small (0); large (1)

From Laurin (1991 H.5), Reisz *et al. (*1992 c.83), Berman *et al. (*1995 c.82), Reisz *et al. (*2010 c.88), Benson (2012 c.186), Ezcurra *et al. (*2010 c.87), Fröbisch et *al. (*2011 c.113), Spindler *et al. (*2018 c.134)

Unambiguous: Araeoscelidia (0to1), Sphenacodontia (0to1), *Protorothyris archeri* (0to1)

246. Sternum: not mineralised (0); mineralised (1)

From Laurin and Reisz (1995 c.100).

A sternum composed of calcified cartilage or bone is present in *Araeoscelis* (Vaughn 1955) and *Youngina* (Smith and Evans 1996).

Unambiguous: *Araeoscelis* spp (0to1). DELTRAN: *Youngina capensis* (0to1). ACCTRAN: Neodiapsida except *Claudiosaurus* (0to1)

247. Humerus, capitellum (radial condyle) and trochlea (ulnar condyle): strongly developed as distinct ball-shaped and saddle-shaped structures (0); poorly developed but distinct from the ectepicondyle and entepicondyle (1); indistinct from the ectepicondyle and entepicondyle (2)

From Ezcurra *et al. (*2014 c.198), Pritchard *et al. (*2015 c.156), Ezcurra (2016 c.428)

Almost all early amniotes possess a well-developed capitellum and trochlea (state 0) (e.g. diadectomorphs, Moss 1972; *Limnoscelis*, FMNH UC 676; caseasaurs, Sumida *et al. 2*014, *Casea broilii* FMNH UC 656; ophiacodontids, *Ophiacodon uniformis* MCZ 5935; sphenacodontians, *Dimetrodon* sp. MCZ 7074; edaphosaurids, *Edaphosaurus boanerges* MCZ 3417; captorhinids, Fox and Bowman 1966; 'protorothyridids', *Hylonomus* NHM R 4168, *Paleothyris acadiana* MCZ 3485 and araeoscelidian diapsids, Reisz 1981). Character state (1) is present in varanodontines (e.g. *Aerosaurus*, Langston and Reisz 1981 fig.2; *Varanops*, MCZ 1926), neodiapsids (e.g.

Youngina, BP/1/3859, Currie 1980), *Erpetonyx* (Modesto *et al. 2*015) and *Procolophon* (BP/1/962, deBraga 2003). Character state (2) is present in archosauromorphs (e.g. *Prolacerta* and *Proterosuchus*, Ezcurra 2016) and *Mesosaurus* (Modesto 2010).

Unambiguous: Mesosauridae (1to2), Varanopidae + Neoreptilia (0to1), *Thuringothyris mahlendorffae* (0to1).DELTRAN: Archosauromorpha (1to2).ACCTRAN: *Lanthanolania* + Archosauromorpha (1to2)

248. Humerus, ridge connecting deltopectoral crest to head: double, paired ridge enclosing proximolateral fossa, deltopectoral crest anteroposteriorly expanded and 'tuberous' (0); single, fossa is absent (1)

From Brinkman and Eberth (1983 c.1), Reisz *et al. (*1992 c.85), Berman *et al. (*1995 c.88) Benson (2012 c.192), Spindler *et al. (*2018 c.150)

Brinkman and Eberth (1983 fig.13) noted a distinctive double ridge, enclosing a fossa, connecting the distal tip of the deltopectoral crest to the femoral head in caseids and varanodontines. The double ridge is absent (state 1) in sphenacodontians, edaphosaurids and ophiacodontids. It is also absent in araeoscelidian diapsids (e.g. *Petrolacosaurus*, Reisz 1981 and *Araeoscelis*, Vaughn 1955).

Unambiguous: Araeoscelidia (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

249. Humerus, diaphysis (shaft): absent, distal and proximal heads merge and lack discrete shaft (0); distinct shaft present (1)

From Laurin and Reisz (1995 c.104), Reisz *et al. (*2007 c.104), Tsuji *et al. 2*012 c.111)

In the current taxon list state (0) is found only in diadectamorphs (e.g. *Tseajaia*, Moss 1972; *Limnoscelis*, FMNH UC 676) and *Seymouria* (FMNH C.145).

Unambiguous: Amniota (0to1).

250. Humerus, ratio of width of distal head to humerus length: equal to or greater than 0.40 (0); less than 0.40 (1)

Modified from Laurin (1991 D.4), Reisz *et al. (*2010 c.89), Nesbitt (2011 c.235), Ezcurra *et al. (*2014 c.88), Spindler *et al. (*2018 c.155)

State (1) describes the slender distal humerus that occurs in early varanopids and mycterosaurines (e.g. *Apsisaurus*, Laurin 1991; *Heleosaurus*, Botha-Brink and

Modesto 2009; *Ascendonanus*, Spindler *et al. 2*018), 'protorothyridids' (e.g., *Hylonomus*, Carroll 1964; *Paleothyris,* Carroll 1969), araeoscelidians (e.g. *Petrolacosaurus*, Reisz 1981; *Araeoscelis*, Vaughn 1955) and neodiapsids (e.g. *Youngina*, BP/1/3859; *Claudiosaurus,* MNHN 1978-6-1 and -2). It is also found in *Mesosaurus* and *Stereosternum* (Modesto 2010, Modesto 1999). The state threshold for this character was originally set at 30% of the humeral shaft e.g. Laurin (1991), Reisz *et al. (*2010), Ezcurra *et al. (*2014). Nesbitt (2011) revised the ratio measurement to the humeral length/distal width rather than the more subjective shaft length, but maintained the 30% threshold. Spindler *et al. (*2018) maintained this definition, but increased the threshold to 50%. We find that for the current taxon list a threshold of 40% defines a phylogenetically consistent morphology in some groups of early amniotes.

Unambiguous: Varanodontinae (1to0), Parareptilia except Mesosauridae (1to0), Reptilia except Captorhinidae (0to1). DELTRAN: *Emeroleter levis* (0to1). ACCTRAN: Pareiasauria + Nycteroleteridae (0to1)

251. Humerus, entepicondylar foramen: present (0); absent (1)

From Gauthier *et al. (*1988 c.164), Laurin (1991 F.6), Laurin and Reisz (1995 c.103), Müller (2004 c.65), Reisz *et al. (*2010 c.91, Ezcurra *et al. (*2014 c.90), Pritchard *et al. (*2015 c.153), Modesto *et al. (*2015 c.146), Ezcurra (2016 c.426)

The absence of the entepicondylar foramen (state 1) is a synapomorphy of Archosauromorpha (Laurin 1991), and is scored as state (1) in *Prolacerta* (Gow 1975) and *Proterosuchus* (Ezcurra *et al. 2*013). The entepicondylar foramen is also absent in owenettid parareptiles (e.g. *Owenetta* and *Barasaurus*, Reisz and Scott 2002). Laurin and Reisz (1995) considered the derived state an autapomorphy of *Mesosaurus*, but the presence of an entepicondylar foramen in *Mesosaurus* is clearly shown in Modesto (2010 figs.3, 5, 10).

DELTRAN: Archosauromorpha (0to1), *Owenetta kitchingorum* (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), Owenettidae (0to1)

252. Humerus, entepicondyle (ulnar epicondyle), transverse width: moderate makes up just less than half of transverse width of distal expansion (0); reduced or confluent with the ectepicondyle (1); enlarged, makes up more than 2/3 of the distal transverse width (2)

Modified from Laurin (1991 F.6), Berman *et al. (*1995 c.86), Reisz *et al. (*2010 c.90), Benson (2012 c.199), Ezcurra *et al. (*2014 c.89), Ezcurra (2016 c.245)

Unambiguous: Varanodontinae (1to0), *Acerosodontosaurus piveteaui* (1to0), *Claudiosaurus germaini* (1to0), Varanopidae + Neoreptilia (0to1), Anthracodromeus hamiltonensis (0to1). DELTRAN: *Procolophon trigoniceps* (1to2), *Ophiacodon* spp (0to2). ACCTRAN: Parareptilia except Mesosauridae (1to2), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to2)

253. Humerus, ectepicondylar (radial epicondylar) foramen: absent, ectepicondylar groove not enclosed and supinator process proximodistally short (0); present (1); long supinator process, but epicondylar foramen not enclosed (2); supinator process very low or absent (3)

Modified from Benson (2012 c.198) modified from Laurin (1993 c.103), Berman *et al. (*1995 c.87), Sidor and Hopson (1998 c.142, 143), Maddin *et al. (*2008 c.87), Fröbisch et *al. (*2011 c.79), MacDougall and Reisz (2014 c.145), Modesto *et al. (*2015 c.145)

In most early amniotes the supinator process is proximodistally short, and forms a small, unclosed groove or notch on the posterior surface of the humerus (state 0). Early caseids possess a long supinator process, which does not fully enclose the ectepicondyle, but instead forms an elongate open groove (state 2) (Olsen 1968). The foramen is virtually absent and the supinator process is not differentiated from the ectepicondyle to any marked degree (state 3) in 'protorothyridids' (e.g. *Hylonomus*, Carroll 1964; *Protorothyris*, Clark and Carroll 1973) and captorhinids (e.g. *Protocaptorhinus*, MCZ 1473). Several terminal taxa have a fully enclosed ectepicondylar foramen (state 1)(e.g. *Edaphosaurus*, MCZ 3417; *Ascendonanus*, Spindler *et al. 2*018; *Heleosaurus*, Botha-Brink and Modesto 2009; *Araeoscelis*, Vaughn 1955; *Acerosodontosaurus*, Bickelmann *et al. 2*009 and some early parareptiles, Modesto 2010, Modesto *et al. 2*015).

Unambiguous: *Ascendonanus nestleri* (0to1), *Acerosodontosaurus piveteaui* (0to1), *Deltavjatia rossicus* (1to0), *Nyctiphruretus* + Procolophonoidea (1to0), Parareptilia (0to1), Caseidae (0to2), *Edaphosaurus boanerges* (0to1), *Protorothyris archeri* (0to3), *Hylonomus lyelli* (0to3), *Araeoscelis* spp (0to1). DELTRAN: *Eudibamus cursoris* (1to0), Captorhinidae except *Euconcordia* (0to3), *Heleosaurus scholtzi* (0to1). ACCTRAN: *Eudibamus cursoris* + *Belebey vegrandis* (1to0), Captorhinidae (0to3), *Elliotsmithia* + *Mesenosaurus* + *Heleosaurus* (0to1)

254. Humerus, supinator process: transversely broad and extends laterally or anterolaterally (0); transversely narrow and almost confluent with humeral shaft (1); inapplicable, supinator process is low or absent (-)

Modified from Laurin and Reisz (1995 c.101), deBraga and Rieppel (1997 c.126), Reisz *et al. (*2007 c.101), Schoch and Sues (2015 c.125), Modesto *et al. (*2015 c.143), Modesto *et al. (*2018 c.72 in part)

The supinator process is parallel or confluent with the humeral shaft (state 1) in

Heleosaurus (Botha-Brink and Modesto 2009), *Apsisaurus* (Laurin 1991), araeoscelidians (Reisz 1981, Vaughn 1955), neodiapsids (Gow 1975, *Claudiosaurus* MNHN 1978-6-1 and -2) and parareptiles (Modesto *et al.* 2015, Reisz *et al.* 2007).

Unambiguous: Diapsida (0to1), Varanodontinae (1to0).

255. Radius-humerus, length ratio: less than 0.68 (0); 0.68 to 0.82 (1); greater than 0.82 (2)

From Ezcurra *et al.* (2014 c.92) modified from Laurin (1991 A.6, H.7). Reisz *et al.* (2010 c.93), Nesbitt (2011 c.241), Ezcurra (2016 c.435), Spindler *et al.* (2018 c. 158)

Unambiguous: Araeoscelidia (0to2), *Thuringothyris mahlendorffae* (0to2), *Tseajaia campi* (0to1), *Varanodon agilis* (1to0), *Varanops brevirostris* (1to2). DELTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (0to1), *Youngina capensis* (0to1), Archosauromorpha (0to2), Erpetonyx arsenaultorum (0to1), *Owenetta kitchingorum* (0to1), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), Sphenacodontia (0to1), *Heleosaurus scholtzi* (1to2). ACCTRAN: Mycterosaurinae (1to2), Varanopidae except *Ascendonanus* (0to1), *Lanthanolania* + Archosauromorpha (1to2), Neodiapsida except *Claudiosaurus* (0to1), Owenettidae (0to1), Bolosauria (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

256. Radius, length: shorter than ulna (0); longer than or approximately of the same length as the ulna (1)

Ezcurra *et al.* (2014 c.202) modified from Rieppel (1999 c.98), Müller (2004 c.66), Ezcurra (2016 c.436)

The proximodistal measurement of the ulna does not include the olecranon process.

Unambiguous: Parareptilia except Mesosauridae and Bolosauria (1to0), Diapsida (0to1), *Watongia meieri* (1to0). DELTRAN: *Ophiacodon* spp (0to1), *Dimetrodon* spp (0to1), *Edaphosaurus boanerges* (0to1). ACCTRAN: Sphenacodontidae + *Cutleria wilmarthi* (0to1), Sphenacodontia (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

257. Radius, shape: straight (0); distinctly sigmoidal in lateral view (1)

From Laurin (1991 I.3), Reisz *et al.* (2010 c.94), Ezcurra *et al.* (2010 c.93), Ezcurra (2016 c.437)

The radius is sigmoidal or 'twisted' in lateral view in *Youngina* (Gow 1975) and *Acerosodontosaurus* (Bickelmann *et al.* 2009).

Unambiguous: *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1). DELTRAN: *Euromycter rutena* (0to1). ACCTRAN: *Euromycter rutena* + *Ennatosaurus tecton* (0to1)

258. Ulna, olecranon process: absent or very low (0); prominent but lower than its transverse depth at base (1); strongly developed, being higher than its transverse depth at base (2)

Modified from Ezcurra *et al. (*2014 c.94), Laurin (1991 C.2), Laurin and Reisz (1995 c.105), deBraga and Rieppel (1997 c.130) modified from Müller (2004 c.147), Reisz *et al. (*2010 c.95), Modesto *et al. (*2015 c.148), Pritchard *et al. (*2015 c.157 in part), Ezcurra (2016 c. 430)

Unambiguous: *Procolophon trigoniceps* (0to1), Varanopidae + Neoreptilia (2to0), *Thuringothyris mahlendorffae* (2to1), Amniota (1to2), *Haptodus garnettensis* (2to1). DELTRAN: *Deltavjatia rossicus* (0to1), *Macroleter poezicus* (0to1), *Ennatosaurus tecton* (2to1), Casea broilii (2to1), *Cutleria wilmarthi* (2to0), *Pantelosaurus saxonicus* (2to0), *Varanops brevirostris* (0to1), *Aerosaurus wellesi* (0to1), *Mesenosaurus romeri* (0to1). ACCTRAN: Mycterosaurinae + Varanodontinae (0to1), *Emeroleter levis* (1to0), Pareiasauria + Nycteroleteridae (0to1), *Euromycter rutena* (1to2), Caseidae (2to1), Sphenacodontidae (0to2), Sphenacodontia (2to0), *Varanodon agilis* + *Watongia meieri* (1to0), *Heleosaurus scholtzi* (1to0)

259. Carpus, width to length ratio of radiale: subequal or less than 1.0 (0); greater than 1.0 (1)

From Reisz and Laurin (2004 c.56), Maddin *et al. (*2006 c.55), Benson (2012 c.201)

DELTRAN: Casea broilii (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to0). ACCTRAN: Synapsida (1to0), *Euromycter rutena* + *Ennatosaurus tecton* (0to1)

260. Carpus, ulnare proximodistal proportions: longer than wide, width less than 0.7 times length (0); short, width equal to or greater than 0.7 times length (1)

From Benson (2012 c.204) modified from Bickelmann *et al. (*2009 c.188)

Unambiguous: *Euromycter rutena* (1to0). DELTRAN: Erpetonyx arsenaultorum (1to0), Araeoscelidia (1to0), *Ophiacodon* spp (1to0), Sphenacodontia (1to0), *Paleothyris acadiana* (1to0). ACCTRAN: Bolosauria (1to0), Varanopidae + Neoreptilia (0to1), Reptilia except Captorhinidae (1to0), Edaphosauridae (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (1to0)

261. Carpus, transverse width across carpus at widest point (excluding pisiform): subequal to or greater than 4th metacarpal (0); less than 4th metacarpal (1)

Modified from Laurin and Reisz (1995 c. 114 in part)

Heaton and Reisz (1986) noted that the presence of a broad carpus/tarsus and short metacarpals/metatarsals (state 0) is a primitive condition in amniotes, and that the maximum transverse width of the carpus/tarsus is less than the length of the longest metacarpal/metatarsal in more derived taxa (state 1). In the current taxon list, state (1) is present in early varanopids and mycterosaurines (e.g. *Ascendonanus*, Spindler *et al. 2*018 and *Heleosaurus*, Botha-Brink and Modesto 2009), *Paleothyris*(Heaton and Reisz 1986) and araeoscelidians (Reisz 1981, Vaughn 1955), *Youngina* (Smith and Evans 1996) and *Prolacerta* (Gow 1975).

Unambiguous: Varanodontinae (1to0), *Acerosodontosaurus piveteaui* (1to0), *Emeroleter levis* (0to1), Reptilia except Captorhinidae (0to1). DELTRAN: *Claudiosaurus germaini* (1to0), Parareptilia (1to0), ACCTRAN: Neodiapsida except *Claudiosaurus* (0to1), Neoreptilia (1to0)

262. Carpus, pisiform size: subequal to or smaller than the 4th distal carpal (0); conspicuously larger than the 4th distal carpal (1)

Modified from Spindler *et al. (*2018 c.163)

Spindler *et al.* (2018, online resource 3 c.163) noted that a large pisiform is characteristic of 'pelycosaur'-grade synapsids and captorhinids, although did not suggest a comparative method for defining its size. Herein we compare the size of the pisiform to the 4th distal carpal of the manus. We find that the pisiform is enlarged (state 1) in those early synapsids where both elements are preserved (e.g. *Ophiacodon* and *Dimetrodon*, Romer and Price 1940; *Edaphosaurus*, MCZ 4320; *Varanops*, Williston 1911 plate VIII, Olson 1965 fig.4E, *Watongia*, Reisz and Laurin 2005 fig. 5B) and in the neodiapsid *Claudiosaurus* (Carroll 1981 fig.19D and MNHN 1978-6-1). However, it is subequal to the 4th distal carpal (State 0) in *Casea* (Williston 1911). In *Captorhinus aguti* the pisiform is also subequal in size to the 4th distal carpal (Holmes 1977 fig. 10A and Fig. 11E).

Unambiguous: *Limnoscelis paludis* (0to1), *Pantelosaurus saxonicus* (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1).DELTRAN: *Claudiosaurus germaini* (0to1), *Stereosternum tumidum* (0to1). Varanodontinae except *Aerosaurus wellesi* (0to1), ACCTRAN: Neodiapsida except *Claudiosaurus* (1to0), Parareptilia except Mesosauridae (1to0), Varanopidae + Neoreptilia (0to1)

263. Metacarpus, length of McIV: less than 45% of radius length (0); greater than 45% (1)

From Spindler *et al. (*2018 c.165) modified from Maddin *et al. (*2008 c. 57), Campione and Reisz (2010 c.56), Benson (2012 c.205), Reisz and Fröbisch (2014 c.93)

The manus is proximodistally elongate compared to the zeugopodium (state 1) in several terminal taxa (e.g. varanodontines, Olson 1965, Williston 1911, Reisz and Laurin 2004; *Ascendonanus*, Spindler *et al. 2*018; *Paleothyris,* Carroll 1969; *Youngina*, Gow 1975 and *Erpetonyx,* ROM 55402).

Unambiguous: *Youngina capensis* (0to1), *Thuringothyris mahlendorffae* (0to1). DELTRAN: Varanodontinae (0to1), *Ascendonanus nestleri* (0to1), Erpetonyx arsenaultorum (0to1), *Paleothyris acadiana* (0to1). ACCTRAN: Mycterosaurinae (1to0), Bolosauria (0to1), Varanopidae (0to1), 'protorothyridids' (0to1)

264. Metacarpus, McV to McIV length ratio: greater than 0.65 (0); less than 0.65 (1)

Modified from deBraga and Rieppel (1997 c.132), Reisz and Laurin (2004 c.57), Maddin *et al. (*2006 c.56), Reisz *et al. (*2009 c.68), Benson (2012 c.207)

Unambiguous: *Youngina capensis* (0to1), *Watongia meieri* (1to0). DELTRAN: Varanopidae (0to1), *Thuringothyris mahlendorffae* (0to1), *Petrolacosaurus kansensis* (0to1). ACCTRAN: Neoreptilia (1to0), Captorhinidae except *Euconcordia* and *Thuringothyris* (1to0), Reptilia (0to1)

265. Manus, ungual (terminal) phalanges, height to width ratio: low, ratio <1.1 and blood vessel grooves may be visible on the dorsolateral surface of the phalanx (0); high, ratio >1.5, strongly recurved and blood vessel grooves are located on the lateral surface of the phalanx (1)

Modified from Maddin *et al. (*2006 c.58), Maddin *et al. (*2008 c.95), Reisz *et al. (*2009 c.69), Benson (2010 c.212)

Unambiguous: *Ascendonanus nestleri* (0to1), Sphenacodontia + Edaphosauridae (0to1). DELTRAN: *Procolophon trigoniceps* (0to1). ACCTRAN: Parareptilia except Mesosauridae (0to1)

266. Manus, ungual (terminal) phalanges, shape: hoof-like or bluntly spade-shaped distally with no ventral curvature (0); taper distally to a point, and curve ventrally (1)

NEW

A keratinous claw, which sheaths the ungual (terminal) phalanx of the manus, is considered to be a feature unique to amniotes (Maddin and Reisz 2007). In all amniote taxa included in the current study where the manual unguals are known, with the exception of mesosaurids, the ungual tapers to a point distally with a distinct ventral curvature (state 1). In *Stereosternum* and *Mesosaurus*, the manual unguals are bluntly spade-shaped (state 0)(Modesto 1999, Modesto 2010). In out-group taxa such as *Seymouria* (White 1939) and diadectomorphs (e.g. *Tseajaia*, Moss 1972 and *Limnoscelis*, Kennedy 2010) the ungual phalanx is hoof-like (state 0), although a keratinous sheaf may have been present in life based on a series of pits and grooves on the distal surface of the phalanx in *Diadectes absitus* (Maddin and Reisz 2007). The stem-amniote *Gephyrostegus* is shown by Carroll (1970 fig.2) to possess small tapering manual unguals, however, postcranial remains attributed to this taxon are possibly related to other taxa (Clack 2012) and *Gephyrostegus* is scored as (?) herein.

Unambiguous: Mesosauridae (1to0), Amniota (0to1)

267. Pelvic girdle, acetabulum: elongate, sub-oval and shallow (0); subcircular and deep (1)

Modified from Laurin (1991 B.7) Reisz *et al. (*2010 c.100), Benson (2012 c.214), Ezcurra *et al. (*2014 c.99), Ezcurra 2016 (c.469 in part)

Unambiguous: Neoreptilia (0to1), *Youngina capensis* (1to0).

268. Pubis, anteroposterior length relative to acetabulum:>1.5 times (0); 1.0-1.5 times (1)

From Benson (2012 c. 218), modified from Sidor and Hopson (1998 c.161), Ezcurra (2016 c.472).

In diadectomorphs (e.g. *Tseajaia*, Moss 1972 and *Limnoscelis*, Romer 1946, Kennedy 2010) the pubis is short anteroposteriorly when compared to the length of the acetabulum (state 1). This condition is also present in *Captorhinus aguti* (Fox and Bowman 1966), and some araeoscelidians and neodiapsids (e.g. *Petrolacosaurus*, Reisz 1981 fig.18; *Youngina*, BP/1/3859; *Acerosodontosaurus*, Currie 1980 and *Prolacerta*, Gow 1975). In the early varanopid *Archaeovenator,* the pubis is unusually short anteroposteriorly compared to early synapsids (MCZ 12483, Reisz and Dilkes 2003), and is scored as state (1) herein.

Unambiguous: Diadectomorpha (0to1), *Petrolacosaurus kansensis* (0to1).
DELTRAN: *Prolacerta broomi* (0to1), *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), *Captorhinus aguti* (0to1), *Archaeovenator hamiltonensis* (0to1).
ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1),

Proterosuchus spp (1to0), Neodiapsida (0to1), Captorhinidae (0to1)

269. Pubis, ventrolateral surface of pubic apron: flat or convex, pubes extends ventromedially (0); strongly concave, pubes extend approximately medially (1).

From Benson (2012 c.221)

In the varanodontine *Varanops*, the ventral region of the pubic apron inclined medially, forming a strongly concave region on the ventrolateral surface (MCZ 1926, Campione and Reisz 2010 fig.13). The same condition can be found in sphenacodontians (e.g. *Dimetrodon*, MCZ 1365, Romer and Price 1940 plate 28), some mycterosaurines (e.g. *Heleosaurus*, *Mycterosaurus*) and araeoscelidian diapsids (e.g. *Petrolacosaurus*, Reisz 1981 fig.18 and *Araeoscelis*, Vaughn 1955 fig.11)

Unambiguous: *Mesenosaurus romeri* (1to0). DELTRAN: Mycterosaurinae + Varanodontinae (0to1), Araeoscelidia (0to1), Sphenacodontia except *Haptodus* (0to1). ACCTRAN: Neoreptilia (1to0), Diapsida (0to1), Sphenacodontia (0to1)

270. Pubis, pubic tubercle anteroventral to acetabulum: absent (0); present, projects laterally (1); present, projects dorsally (2); highly striated region bounded by a longitudinal crest dorsally (3)

Modified from Benson (2012 c.219) modified from Reisz *et al.* (1992 c.90), Berman *et al.* (1995 c.91), Maddin *et al.* (2008 c.100), Spindler *et al.* (2018 c.139)

Character state (3) of Benson (2012 c.219) is omitted since the derived caseids scored for this state are not included in the current taxon list. *Edaphosaurus* is scored as state (3) herein, i.e. state (4) in Benson (2012), although this is parsimony uninformative, and is included for information purposes only.

Unambiguous: *Ascendonanus nestleri* (1to0), *Ophiacodon* spp (2to0). DELTRAN: *Mesosaurus tenuidens* (1to0), *Captorhinus aguti* (1to2), Casea broilii (1to2), Ophiacodontidae except *Echinerpeton* (1to2), *Edaphosaurus boanerges* (1to3), *Mycterosaurus longiceps* (1to2). ACCTRAN: Mycterosaurinae (1to2), Mesosauridae (1to0), Captorhinidae (1to2), Caseidae (1to2), Edaphosauridae (1to3), Ophiacodontidae (1to2)

271. Ilium, medial surface: weakly concave or flat (0); anteroventrally oriented ridge contacts pubic articulation (1)

From Benson (2012 c.215).

In *Limnoscelis*, ophiacodontids (e.g. *Varanosaurus*, MCZ 1353, Benson 2012 appendix 1 fig. A9B), *Varanops*, (Benson 2012 appendix 1 fig. A9D), *Captorhinus aguti* (Fox and Bowman fig.32), some ‘protorothyridids’ (e.g. *Hylonomus*, Carroll 1964 and *Paleothyris,* MCZ 3485, Carroll 1969) and *Petrolacosaurus* (Reisz 1981 fig.18) a ridge on the medial surface of the ilium extends anteroventrally to the suture with the pubic plate.

Unambiguous: Amniota + Diadectomorpha (0to1), Sphenacodontia + Edaphosauridae (1to0). DELTRAN: Varanopidae + Neoreptilia (1to0), Casea broilii (1to0), *Araeoscelis* spp (1to0), *Varanops brevirostris* (0to1). ACCTRAN: Varanodontinae (0to1), Diapsida (1to0), Caseidae (1to0), *Petrolacosaurus kansensis* (0to1)

272. Ilium, dorsal process morphology: long, tapering posterodorsal blade, extending beyond the posterior edge of iliac body, anterodorsal blade small or absent (0); marked anterodorsal expansion present, dorsal process tall and plate-like (1); dorsal expansion directly above acetabulum, short posteriorly, not extending beyond posterior edge of iliac body (2)

Modified from Benson (2012 c.216) modified from Reisz *et al. (*1992 c.88, 89), Laurin (1993 c.107), Modesto (1994 c.34), Laurin and Reisz (1995 c.108), Berman *et al. (*1995 c.90), Maddin *et al. (*2008 c.97), Fröbisch *et al. (*2011 c.82), Modesto *et al. (*2015 c.152), Spindler *et al. 2*018 c.135)

Most terminal taxa, where the ilium is known, share state (0). Caseasaurs (Sumida *et al. 2*014, Olson 1968, FMNH UC 656), sphenacodontians (Romer and Price 1940, MCZ 1114) and edaphosaurids (Romer and Price 1940) share a posterodorsally directed plate-like ilium with an anterodorsal projection (state 1). In some parareptiles the ilium has a short, dorsally orientated process with limited posterior or anterior projection (state 2) (e.g. *Procolophon*, deBraga 2003; *Milleretta*, Gow 1972).

Unambiguous: Parareptilia except Mesosauridae and Bolosauria (0to2). DELTRAN: *Owenetta kitchingorum* (2to0), Sphenacodontia + Edaphosauridae (0to1), Caseasauria (0to1). ACCTRAN: Owenettidae (2to0), Synapsida (0to1), Ophiacodontidae (1to0)

273. Ilium, mediolateral expansion on dorsal surface: absent, ilium is plate-like with no mediolateral expansion along the dorsal surface (0); present, and forms a trough or well-defined fossa (1); present, and forms a shelf with no discernable fossa (2)

Modified from Reisz *et al. (*1992 c.87), Laurin (1993 c.106), Laurin and Reisz (1995 c.107), Berman *et al. (*1995 c.89), Maddin *et al. (*2008 c.98), Fröbisch et *al. (*2011 c.81), Benson (2012 c.217), Modesto *et al. (*2015 c.151)

Many early amniotes possessed ilia with mediolaterally thin, plate-like dorsal margins (e.g. *Seymouria*, caseasaurs, sphenacodontians, edaphosaurids, *Ascendonanus*, *Varanops*, *Mesosaurus* and several neodiapsids. State (1), in which the mediolaterally expanded dorsal surface of the ilium forms a double ridge and longitudinal fossa, is present in *Limnoscelis* (Romer 1946), ophiacodontids (Romer and Price 1940) and *Petrolacosaurus* (Reisz 1981). Other taxa possessed a flat shelf along the dorsal surface of the ilium, but with no fossa (e.g. *Tseajaia*, Moss 1972; *Aerosaurus*, Langston and Reisz 1981; *Archaeovenator*, Reisz and Dilkes 2003; *Paleothyris,* Carroll 1969, MCZ 3481, 3485; *Captorhinus aguti*, Holmes 2003 and *Araeoscelis*, Reisz 1981, Vaughn 1955). Modesto *et al. (*2015) scored for state (2) in the bolosaurid parareptile *Eudibamus*. A mediolateral expansion (state 2) is also present on the dorsal surface of the ilium in *Erpetonyx* (ROM 55402).

Unambiguous: Bolosauria (0to2), Neoreptilia (2to0), *Limnoscelis paludis* (2to1), *Hylonomus lyelli* (2to0), *Petrolacosaurus kansensis* (2to1). DELTRAN: Reptilia (0to2), *Tseajaia campi* (0to2), *Varanosaurus acutirostris* + *Ophiacodon* spp (0to1), *Varanops brevirostris* (2to0). ACCTRAN: Synapsida (2to0), Amniota + Diadectomorpha (0to2), Ophiacodontidae (0to1), Varanodontinae except *Aerosaurus wellesi* (2to0)

274. Ischium, shape: slender, tapering posteriorly (0); expanded posterodorsally (1)

Reisz *et al. (*1992 c.91), Fröbisch et *al. (*2011 c.116), Benson (2012 c.222)

Unambiguous: Sphenacodontia + Edaphosauridae (0to1).

275. Hindlimb-trunk, length ratio: hindlimb much shorter than trunk (0); hindlimb not less than 90% of the anteroposterior length of the trunk or longer (1)

Modified from Reisz *et al. (*2010 c.101), Ezcurra *et al. (*2014 c.100), Spindler *et al. (*2018 c.143)

For clarity, we define the trunk as that part of the torso between the fore and hindlimbs, represented by the anteroposterior length of the dorsal vertebral series. *Araeoscelis* (Vaughn 1955, MCZ 4380) and neodiapsids (e.g. *Claudiosaurus,* MNHN 1978-6-1 and *Youngina*, Smith and Evans 1996 fig.4), some mycterosaurines (e.g. *Mycterosaurus*) and varanodontines (e.g. *Aerosaurus* and *Varanops*) possessed relatively long hindlimbs (state 1). The parareptile *Eudibamus* possessed an unusually elongate hindlimb, suggesting facultative bipedalism (Berman *et al.* 2000).

DELTRAN: Mycterosaurinae + Varanodontinae (0to1), *Eudibamus cursoris* (0to1), Neodiapsida (0to1), Araeoscelidia (0to1). ACCTRAN: *Ascendonanus nestleri* (1to0), Bolosauria (0to1), Parareptilia (1to0), Diapsida (0to1)

276. Femur, distal articular surface: uneven, posterior (fibular) condyle projecting distinctly beyond the anterior (tibial) condyle (0); both condyles extend distally to approximately at same level (1)

Modified from Gauthier *et al. (*1988 c.187), Laurin (1991 B.8), Müller (2004 c.72), Reisz *et al. (*2010 c.102), Fröbisch et *al. (*2011 c.88), Benson (2012 c.232 with states (1) and (2) combined), Ezcurra *et al. (*2014 c.101), Spindler *et al. (*2018 c.169)

Eothyridids and *Eocasea* possess state (1) (Brocklehurst *et al. 2*016, Sumida *et al. 2*014), as do some neodiapsids (e.g. *Acerosodontosaurus*, Currie 1980; *Claudiosaurus,* MNHN 1978-6-1; *Proterosuchus*, Ezcurra 2016) and some parareptiles (e.g. *Mesosaurus*, Modesto 2010, *Stereosternum*, Modesto 1999 and *Milleretta*, Gow 1972). *Prolacerta* (Ezcurra 2016) and *Erpetonyx* (ROM 55402) are scored as state (0). In sphenacodontians, edaphosaurids, ophiacodontids, and varanopids the fibular condyle extends beyond the tibial condyle (state 0), except in the varanodontine *Aerosaurus* (Laurin 1991), which is scored as state (1).

Unambiguous: Apsisaurus witteri (0to1), *Prolacerta broomi* (1to0), Erpetonyx arsenaultorum (1to0), Neoreptilia (0to1), Eothyrididae (0to1). DELTRAN: Ankyramorpha except Lanthanosuchoidea (1to0). ACCTRAN: Ankyramorpha (1to0)

277. Femur, length to humerus ratio: greater than or equal to 1.2 (0); less than 1.2 (1)

Modified from Laurin (1991 C.3), Reisz *et al. (*2010 c.104), Nesbitt (2011 c.231), Ezcurra *et al. (*2014 c.103), Ezcurra (2016 c.489 in part), Spindler *et al. (*2018 c.145)

The femur is longer than the humerus by at least 20% in several terminal taxa; mycterosaurines (e.g. *Apsisaurus*, Laurin 1991), varanodontines (e.g. *Varanops*, MCZ 1926), neodiapsids (e.g. *Youngina*, Smith and Evans 1996 and *Prolacerta*, Gow 1975), and parareptiles (e.g. *Eudibamus*, Berman *et al. 2*000) and *Milleretta*, Gow 1972). In *Ophiacodon* the condition is polymorphic (Romer and Price 1940 table 5).

Unambiguous: Neodiapsida except *Claudiosaurus* (0to1), *Thuringothyris mahlendorffae* (0to1). DELTRAN: Apsisaurus witteri (0to1), *Eudibamus cursoris* (0to1), *Emeroleter levis* (0to1), *Owenetta kitchingorum* (0to1), *Milleretta rubidgei* (0to1), *Varanops brevirostris* (0to1). ACCTRAN: Varanopidae except *Ascendonanus* (0to1), Erpetonyx arsenaultorum (1to0), *Deltavjatia rossicus* (1to0), *Procolophon trigoniceps* (1to0), Parareptilia except Mesosauridae (0to1), *Aerosaurus wellesi* (1to0)

278. Femur, proportions: short and broad, maximum length less than three times distal width (0); long and slender, maximum length more than three times distal width (1).

From Reisz *et al. (*1998 c.21) modified from Reisz *et al. (*1992 c.84), Laurin and Reisz (1995 c.113) Maddin *et al. (*2006 c.60), Reisz *et al. (*2007 c.113), Reisz *et al. (*2009 c.66), Reisz *et al. (*2010 c.103), Benson (2012 c.224), Ezcurra *et al. (*2014 c.102), Modesto *et al. (*2015 c.157), Spindler *et al. (*2018 c.167)

Character state (1), in respect to the current taxon list, is present in all early varanopids and mycterosaurines (e.g. *Archaeovenator*, KUVP 12483 and *Apsisaurus*, Laurin 1991), araeoscelidians and neodiapsids (e.g. *Petrolacosaurus*, Reisz 1981 and *Youngina*, Gow 1975), parareptiles (e.g. *Stereosternum*, Modesto 1999, *Mesosaurus*, Modesto 2010 and *Erpetonyx,* ROM 55402), and the 'protorothyridid' *Paleothyris*(MCZ 3490). It is also found in sphenacodontids, (e.g. *Secodontosaurus*, MCZ 5355, 8677) and is polymorphic in *Dimetrodon* spp. (Romer and Price 1940 table 5).

Unambiguous: Varanodontinae (1to0), *Deltavjatia rossicus* (1to0), Reptilia except Captorhinidae (0to1). DELTRAN: *Secodontosaurus obtusidens* (0to1). ACCTRAN: Sphenacodontia except *Haptodus* (0to1)

279. Femur, 4th trochanter: present as a raised ridge on the ventral surface of the femoral shaft (0); absent (1)

From Gauthier *et al. (*1988 c.193) modified from Nesbitt (2011 c.315, 316 in part), Benson (2012 c.228), Ezcurra (2016 c.504 in part).

In early amniotes the internal trochanter of the femur, a conspicuous raised ridge located on the margin of the proximal intertrochanteric fossa, extends distally as a low ridge on the ventral surface of the femur. Close to the distal margin of the intertrochanteric fossa this ridge may increase in height and form an area for the insertion of the coccygeofemoralis called the 4th trochanter (Romer 1956). This series of ridges is often referred to as the ventral ridge system of the femur, i.e. the internal and 4th trochanters (Gauthier *et al.*1988, Benson 2012 c.228). The 4th trochanter is present (state 0) in many early amniotes, and can vary in morphology. It may form a low, angular ridge originating at the posterior margin of the intertrochanteric fossa as in *Ophiacodon* (Romer and Price 1940), or a prominent raised rugose area originating from the anterior margin of the intertrochanteric fossa as in sphenacodontians, edaphosaurids and caseasaurs (Romer and Price 1940, Laurin 1993, Sumida *et al. 2*010, Brocklehurst *et al. 2*016). A 4th trochanter is present in diadectomorphs (e.g. *Tseajaia*, Moss 1972 and *Limnoscelis*, Romer 1946) and the captorhinid *Captorhinus aguti* (Holmes 2003). In the varanodontine *Varanops*, the 4th trochanter is also present as a low but distinctive raised ridge of bone close to the distal anterior margin of the intertrochanteric fossa (MCZ 1926). In other taxa, the 4th trochanter is absent (state 1)(e.g. *Archaeovenator*, Reisz and Dilkes 2003; *Apsisaurus*, Laurin 1991; *Heleosaurus* Botha-Brink and Modesto 2009, *Mycterosaurus* Berman and Reisz 1982), *Paleothyris*(MCZ 3490), araeoscelidians (Reisz 1981, Vaughn 1955), neodiapsids (Gow 1975) and parareptiles (e.g. *Procolophon*, deBraga 2003; *Stereosternum*, Modesto 1999, *Mesosaurus*, Modesto 2010, *Erpetonyx,* ROM 55402).

Unambiguous: Reptilia except Captorhinidae (0to1) DELTRAN: *Varanops brevirostris* (1to0). ACCTRAN: Varanodontinae (1to0)

280. Femur, distal adductor crest on ventral surface: prominent (0); low and feebly developed (1); absent or reduced to a rugosity on the surface of the bone (2).

Gauthier *et al.*1988 c.190 Reisz *et al. (*1992 93), Laurin (1993, 116), Berman *et al. (*1995 93), Fröbisch et *al. (*2011, 91), Ezcurra (2016 c.507)

In some terminal taxa, a low ridge of bone extends distally from the 4th trochanter towards the posterior (fibular) condyle; we refer to this ridge as the distal adductor crest. In some taxa a prominent distal adductor crest extends longitudinally (e.g. *Ophiacodon,* Romer and Price 940) or diagonally (e.g. *Edaphosaurus*, Romer and Price 1940) from the 4th trochanter to the posterior condyle (state 0)(Romer and Price 1940). In others (e.g. sphenacodontians, Romer and Price 1940, Laurin 1993), the distal adductor crest is low (state 1). The distal adductor ridge is absent or is reduced to a flat rugose line of insertion (*linea aspera*)(state 2) in *Archaeovenator* (Reisz and Dilkes 2003), *Apsisaurus* (Laurin 1991), *Mycterosaurus* (Berman and Reisz 1982), *Petrolacosaurus* (Reisz 1981), *Araeoscelis* (Vaughn 1955), *Prolacerta* (Gow 1975), *Proterosuchus*, Ezcurra *et al. 2*013, *Stereosternum* (Modesto 1999), *Mesosaurus* (Modesto 2010) and *Milleretta* (Gow 1972) in respect to the taxa included in this study.

Unambiguous: *Macroleter poezicus* (2to1), Bolosauria (2to1), Diapsida (1to2), *Ophiacodon* spp (1to0). DELTRAN: *Deltavjatia rossicus* (2to0), *Procolophon trigoniceps* (2to0), 'protorothyridids' (0to1), *Thuringothyris mahlendorffae* (0to1), Sphenacodontia (0to1), Ophiacodontidae (0to1). ACCTRAN: *Nyctiphruretus acudens* (0to2), Ankyramorpha (2to0), Captorhinidae except *Euconcordia* and *Thuringothyris* (1to0), Amniota (0to1), Edaphosauridae (1to0), Caseasauria (1to0)

281. Femur, anterior condyle: dorsoventrally thick, at least 0.6 of the dorsoventral depth of the posterior condyle (0); dorsoventrally compressed, approx. 0.5 or less of the dorsoventral depth of the posterior condyle (1)

Modified from Benson (2012 c.233)

The anterior (tibial) condyle of the femur is compressed dorsoventrally relative to the dorsoventral depth of the posterior (fibular) condyle (state 1) in *Seymouria baylorensis* (FMNH UC 1313, White 1939 fig.28C), *Casea broilii* (FMNH UR 656), *Edaphosaurus boanerges* (Benson 2012 appendix S1 fig. A10D), 'protorothyridids' (e.g. *Hylonomus*, Carroll 1964 and *Paleothyris,* Carroll 1969), and *Captorhinus aguti* (Holmes 2003).

Unambiguous: 'protorothyridids' (0to1), *Seymouria* spp (0to1). DELTRAN: *Captorhinus aguti* (0to1), Casea broilii (0to1), *Edaphosaurus boanerges* (0to1). ACCTRAN: Captorhinidae except *Euconcordia* and *Thuringothyris* (0to1), Caseidae (0to1), Edaphosauridae (0to1)

282. Tibia, cnemial crest: low (0); prominent and distinct (1)

From Benson (2012 c.235)

The cnemial crest is a flange of bone that extends distally from the dorsal (extensor) surface of the proximal end of the tibia for the insertion of the triceps femoris. In some taxa it forms a rounded knob of bone proximally. It is a prominent and distinctive element (state 1) in *Seymouria baylorensis* (White 1939), *Limnoscelis* (Kennedy 2010), caseasaurs (e.g. *Oedaleops* and *Vaughnictis*, Brocklehurst *et al.* 2016; *Casea broilii*, FMNH UR 656), sphenacodontids (e.g. *Dimetrodon* and *Secodontosaurus*, Romer and Price 1940), *Edaphosaurus* (Romer and Price 1940), 'protorothyridids' (e.g. *Hylonomus*, Carroll 1964 and *Paleothyris,* Carroll 1969), araeoscelidians (e.g. *Petrolacosaurus*, Reisz 1981 and *Araeoscelis*, Vaughn 1955), *Captorhinus aguti* (Holmes 2003), *Deltavjatia* (Tsuji 2013) and *Procolophon* (deBraga 2003).

Unambiguous: *Deltavjatia rossicus* (0to1), *Procolophon trigoniceps* (0to1), Varanopidae + Neoreptilia (1to0). DELTRAN: *Varanosaurus acutirostris* + *Ophiacodon* spp (1to0). ACCTRAN: Ophiacodontidae (1to0)

283. Tibia, lower leg-foot length, ratio: articulated tibia + tibiale/astragalus longer than articulated 4th metatarsal + digit (0); shorter (1)

From Reisz *et al. (*2010 c.106) modified from deBraga and Reisz (1995 c.33, 42), Ezcurra *et al. (*2014 c.105), Spindler *et al. (*2018 c.171)

Unambiguous: Varanodontinae (1to0), *Varanosaurus acutirostris* (0to1). DELTRAN: *Prolacerta broomi* (1to0), *Eudibamus cursoris* (1to0), *Emeroleter levis* + *Deltavjatia rossicus* (1to0), Varanopidae + Neoreptilia (0to1), Casea broilii (0to1), *Paleothyris acadiana* (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (1to0), Erpetonyx arsenaultorum (0to1), Parareptilia except Mesosauridae (1to0), Araeoscelidia (1to0), Reptilia except Captorhinidae (0to1), Caseasauria (0to1)

284. Tarsus, tibio-astragalar joint: flat (0); tibial ridge fits into astragalar groove (1); inapplicable, astragalus absent (-)

From Gauthier *et al. (*1988 c.195), Laurin (1991 J.9), Laurin and Reisz (1995 c.116), Reisz *et al. (*2010 c.107)

State (1) was recognised by Laurin and Reisz (1995) as a diapsid synapomorphy, and is scored for araeoscelidians and several neodiapsids in the present study (e.g. *Petrolacosaurus*, Reisz 1981; *Araeoscelis*, Vaughn 1955; *Youngina* and *Prolacerta*, Gow 1975) with the exception of *Claudiosaurus,* in which Carroll (1982) states that the astragalus and calcaneum abut with a nearly flat surface, and this is confirmed in examining specimens MNHN 1978-6-1 and 1978-6-2.

Unambiguous: Neodiapsida except *Claudiosaurus* (0to1), Araeoscelidia (0to1). DELTRAN: *Nyctiphruretus acudens* (0to1). ACCTRAN: *Nyctiphruretus* + Procolophonoidea (0to1)

285. Tarsus, transverse width across tarsus at widest point: subequal to or greater than 4th metatarsal (0); less than 4th metatarsal (1)

Modified from Laurin and Reisz (1995 c.114 in part)

Refer ch.261 above for derivation of this character. State (1) is present in early varanopids, 'protorothyridids', araeoscelidians and neodiapsids.

Unambiguous: *Emeroleter levis* (0to1), Reptilia except Captorhinidae (0to1). DELTRAN: Varanodontinae (1to0), Parareptilia except Mesosauridae and Bolosauria (1to0), *Mesosaurus tenuidens* (1to0). ACCTRAN: Varanopidae except *Ascendonanus*, *Orovenator* and *Archaeovenator* (1to0), *Stereosternum tumidum* (0to1), Parareptilia (1to0)

286. Tarsus, astragalus: absent (0); present (1)

From deBraga and Rieppel (1997 c.148), Benson (2012 c.236), Spindler *et al. (*2018 c.172)

The fusion of the astragalus from independent elements of the tarsus is considered a diagnostic feature of amniotes (Meyer and Anderson 2013). A discrete astragalus is absent in diadectomorphs (Moss 1972, Kennedy 2010), *Seymouria* (Berman *et al. 2*000) and *Gephyrostegus* (Rieppel 1993).

Unambiguous: Amniota (0to1).

287. Tarsus, astragalus, proximal neck region: short (0); long, equal to or > 0.4 of the proximodistal length of astragalus(1); inapplicable, astragalus absent(-)

From Reisz *et al. (*1992 c.95), Fröbisch *et al. (*2011 c.118), Benson (2012 c.238), Spindler *et al. (*2018 c.175)

An elongated proximal region of the astragalus is a derived feature in amniotes. Herein we define the neck region as state (1) if it is equal to or longer than 0.4 of the proximodistal length of the astragalus. The derived state is therefore present in sphenacodontians and edaphosaurids. Reisz and Dilkes (2003) noted that the proximal neck in *Archaeovenator* is longer than other 'varanopids', and examination of KUVP 12483 confirms this taxon should be scored as state 1. State (1) is also scored for *Paleothyris*(MCZ 3481), *Petrolacosaurus* (KUVP 1424), *Erpetonyx* (ROM 55402), *Eudibamus* (Berman *et al. 2*000) and *Procolophon* (deBraga 2003).

Unambiguous: Parareptilia except Mesosauridae (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: *Echinerpeton intermedium* (0to1), Sphenacodontia + Edaphosauridae (0to1), *Paleothyris acadiana* (0to1), *Archaeovenator hamiltonensis* (0to1). ACCTRAN: *Orovenator mayorum* + *Archaeovenator hamiltonensis* (0to1), Ophiacodontidae except *Echinerpeton* (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1), 'protorothyridids' except *Hylonomus* (0to1)

288. Tarsus, calcaneum (fibulare), proportions: length approximately equal to width (0); length conspicuously greater than width (1)

From Reisz *et al. (*1992 c.96), Berman *et al. (*1995 c.94), Fröbisch et *al. (*2011 c.119), Benson (2012 c.239), Spindler *et al. (*2018 c.176)

Unambiguous: Parareptilia except Mesosauridae (0to1), Varanopidae (0to1), *Petrolacosaurus kansensis* (0to1). DELTRAN: Captorhinidae except *Euconcordia* (0to1), Caseidae (0to1), *Varanosaurus acutirostris* (0to1), *Archaeothyris florensis* (0to1), Sphenacodontia (0to1), *Paleothyris acadiana* (0to1), *Varanops brevirostris* (1to0). ACCTRAN: Reptilia except Captorhinidae (1to0), Amniota (0to1), Eothyrididae (1to0), *Ophiacodon* spp (1to0), Edaphosauridae (1to0), *Paleothyris acadiana* + *Protorothyris archeri* (0to1), Varanodontinae except *Aerosaurus wellesi* (1to0)

289. Tarsus, notch or trough for perforating foramen: on astragalus only (0); on the astragalus and calcaneum (1), inapplicable, perforating foramen or astragalus absent (-)

From Spindler *et al. (*2018 c.174) modified from Reisz *et al. (*2010 c.107 in part)

Unambiguous: *Ascendonanus nestleri* (1to0), *Thuringothyris mahlendorffae* (1to0), *Hylonomus lyelli* (1to0). DELTRAN: Erpetonyx arsenaultorum (1to0), *Ennatosaurus* *tecton* (1to0), *Mycterosaurus longiceps* (1to0). ACCTRAN: Mycterosaurinae (1to0), Parareptilia except Mesosauridae (1to0), *Euromycter rutena* + *Ennatosaurus tecton* (1to0)

290. Tarsus, fifth distal tarsal: present (0); absent (1)

From Laurin (1991 E.13), Laurin (1993 c.120), Laurin and Reisz (1995 c.119), Reisz *et al. (*2010 c.112), Ezcurra (2014 c.111), Modesto *et al. (*2015 c.163), Pritchard *et al. (*2015 c.195), Ezcurra (2016 c.563)

The loss of the fifth distal tarsal was considered a synapomorphy of pareiasaurs, procolophonids and testudines (Laurin and Reisz 1995). Benson (2012) recognised that the fifth distal tarsal was also absent in therapsids, a group not represented in the present study. Ezcurra (2016) noted the absence of the fifth distal tarsal in archosauromorphs. It is scored accordingly in *Prolacerta* and *Proterosuchus*.

DELTRAN: Archosauromorpha (0to1), *Procolophon trigoniceps* (0to1), Pareiasauria + Nycteroleteridae (0to1). ACCTRAN: *Lanthanolania* + Archosauromorpha (0to1), *Nyctiphruretus acudens* (1to0), Parareptilia except Mesosauridae (0to1)

291. Tarsus, number of centralia: two centralia present (0); only one centrale is present (1)

Modified from deBraga and Rieppel (1997 c.158), Müller (20041 c.151), Ezcurra *et al. (*2014 c.214), Modesto *et al. (*2015 c.162)

Reisz (1986) noted the presence of two subequal pedal centralia in ophiacodontids, and two in all other 'pelycosaur' ' grade synapsids, although the medial centrale (sensu Romer and Price 1940 fig.35D) is much larger than the lateral centrale. There is some uncertainty, however, in the condition in *Casea broilii*, where some studies consider only one centrale is present (Williston 1911, Olson 1968). Reisz (1986 fig.33D) figures the lateral centrale as a small element in *Casea broilii*, although absent in the more derived caseid *Cotylorhynchus romeri* (Reisz 1986 fig.33E), in accordance with Stovall *et al. (*1966). Consequently *Casea broilii* is coded as (?) herein. The configuration of the tarsus is poorly known in most varanopids, although state (1) is applicable to *Archaeovenator* (Reisz and Dilkes 2003). In respect to the current taxon list, only one pedal centrale (state 1) is present in 'protorothyridids' (Carroll 1964), araeoscelidians and neodiapsids (Reisz 1981, Carroll 1981, Gow 1975) parareptiles (Modesto *et al. 2*015 c.162) and *Captorhinus* (Holmes 2003). In *Nyctiphruretus* and *Emeroleter*, the two centrali are considered present (Tsuji 2012, Müller and Tsuji 2007).

Unambiguous: *Nyctiphruretus acudens* (1to0), Reptilia (0to1). DELTRAN: *Emeroleter levis* (1to0). ACCTRAN: *Emeroleter levis* + *Deltavjatia rossicus* (1to0)

292. Metatarsus, ratio of lengths of metatarsals I and IV: equal or greater than 0.42 (0); less than 0.42 (1)

Modified from Ezcurra *et al. (*2014 c.216) modified from Dilkes (1998 c.123), Müller (2004 c.173), Modesto and Sues (2004 c.123)

A third state, equal to or less than 0.32, was omitted from this character, since it only applied to *Eudibamus* in the current taxon list and was therefore parsimony uninformative.

Unambiguous: *Ascendonanus nestleri* (0to1), *Thuringothyris mahlendorffae* (0to1), *Seymouria* spp (0to1). DELTRAN: *Youngina capensis* (0to1), *Eudibamus cursoris* (0to1), *Ophiacodon* spp (0to1), *Dimetrodon* spp (0to1). ACCTRAN: *Youngina capensis* + *Acerosodontosaurus piveteaui* (0to1), Bolosauria (0to1), Sphenacodontia except *Haptodus* (0to1), Ophiacodontidae (0to1)

293. Metatarsus, metapodials overlapping proximally: absent (0); present (1)

From Laurin and Reisz (1995 c.121), deBraga and Reisz (1995 c.43), Reisz *et al. (*2010 c.110), Ezcurra *et al. (*2014 c.109)

State (1) is present in *Dimetrodon*, *Ophiacodon,* varanopids (with the exception of *Ascendonanus*, Spindler *et al. 2*018), araeoscelidians and neodiapsids. It is also present in *Emeroleter levis* (Tsuji *et al.* 2012)

Unambiguous: *Emeroleter levis* (0to1). DELTRAN: Varanopidae except *Ascendonanus* (0to1), *Eudibamus cursoris* (0to1), Neodiapsida (0to1), Araeoscelidia (0to1), *Ophiacodon* spp (0to1), *Dimetrodon* spp (0to1). ACCTRAN: *Ascendonanus nestleri* (1to0), Bolosauria (0to1), Parareptilia (1to0), Diapsida (0to1), Edaphosauridae (1to0), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1)

294. Metatarsus, fourth metatarsal: short (0); long (at least 40% of digit IV) (1)

From Laurin (1991 F.10), Reisz *et al. (*2010 c.111), Ezcurra *et al. (*2014 c.110)

Unambiguous: *Ascendonanus nestleri* (1to0), Bolosauria (1to0). DELTRAN: Diapsida (0to1), *Limnoscelis paludis* (0to1), Ophiacodontidae + Sphenacodontia + Edaphosauridae (0to1). ACCTRAN: 'protorothyridids' (1to0), Amniota + Diadectomorpha (0to1), Caseasauria (1to0)

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