**Supplementary Data 1**

**Revised Characters**

6. Premaxillary and anterior dentary teeth, distal recurvature of marginal teeth: present (0); absent (1)

*Ford & Benson (2020) scored recurvature, serration and lateral compression for all marginal teeth. With the addition of therapsids, where these traits vary between dental regions, characters 6, 9, and 10 are revised to refer only to premaxillary/anterior dentary teeth. Character 363, 364, 365 are added to score these traits for maxillary/posterior dentary teeth. Anterior dentary teeth are those which oppose the premaxillary teeth.*

9. Premaxillary and anterior dentary teeth, serrations on crown of marginal teeth: absent (0); present (1)

*See note for character 6*

10. Premaxillary and anterior dentary teeth, lateral compression of marginal dentition: only apicially or nowhere (0); over two-thirds of tooth (1)

*See note for character 6*

11. Lateral dentition, number of apical cusps: one (0); three (1); more than three (2).

*Ford & Benson (2020) scored the presence or absence of multiple cusps; with the addition of more casieds, variation in number of cusps was included (as in Benson 2012, character 44)*

18. Premaxilla, slope of alveolar margin relative to ventral margin of maxilla: absent (0); slightly anteroventral, less than 10° from horizontal (1); moderately anteroventral, 10-20° from horizontal (2); strongly anteroventral, 30-45° from horizontal (3); very strongly anteroventral > 45° from horizontal (4); slopes anterodorsally (5).

*Ford & Benson (2020) did not account for the upturned premaxilla of some Character state 2 of Benson (2012), character 13 is added as new state 5. Other states now specify they referred to anteroventral slope*

29. Maxilla, number of tooth rows: single row of marginal teeth only (0); 2-4 (1); 5 or more (2)

*Ford & Benson (2020) originally referred to presence or absence of multiple rows. With the addition of more moradisaurines, separate states accounting for numbers of rows have been added. States taken from Modesto et al. 2014, but since none of the late moradisaurines are included, state 3 (6+ rows) is not here distinguished from state 2.*

44. Maxilla, ventral surface: straight or weakly convex (0); pronounced convexity (1); strongly convex with prominent ‘precanine step’ anteriorly (2).

*Ford & Benson (2020) did not include a character state relating to the precanine step in sphenacodontines. With the addition of sphenacodontines to the matrix, this state was added (as in Benson 2012, character 27)*

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); broad, concave region on lateral surface (4)

*Ford & Benson (2020) did not include a state describing the morphology in* Cotylorhynchus *and* Angelosaurus*. Since these taxa have now been added, this state has been included as state 4 (taken from Benson 2012, state 3)*

**Added Characters**

295. Size of maxillary tooth field: 0) <40, 1) 40 or more. If only single row, inapplicable (Modesto et al. 2014)

296. Mandibular ramus in ventral view: 0) straight; 1) sigmoid (Modesto et al. 2014)

297. Mandibular ramus: 0) narrow, 8% or less of jaw length; 1) broad, at least 14% of jaw length (Modesto et al. 2014)

298. Premaxillary dentition lingual heel: 0) absent; 1) present (Benson 2012, Character 45)

299. Maxilla, lateral surface of anterior process bears deep depression dorsally forming narial rim: no (0); yes (1). Inapplicable if maxilla excluded from naris by premax (Benson 2012, Character 23)

300. Marginal teeth, bulbous base giving a teardrop-shaped outline: 0) absent; 1) present (modified from Benson 2012, character 33)

301: Temporal (postorbital) roof orientation: subhorizontal or weakly inclined posteroventrally (0); strongly inclined posteroventrally, at least 45° (1). (Benson 2012, character 8)

302: Maxilla, ‘lacrimal facet’ at base of dorsal process: absent (0); present, distinct dorsoventral ridge present on ascending process divides anterior and posterior depressions (1). (Beson 2012 character 26)

303: Maxilla and dentary, medial surface adjacent to alveoli: smooth (0): rugose, striated bone encloses tooth bases (1). (Benson 2012 character 28)

304. Maxillary and dentary alveolar ridges: straight (0); twisted (helical), distal teeth inclined laterally (1). (Benson 2012 character 31)

305. Lacrimal lateral surface of anterior process bears deep depression forming narial rim: no (0); yes (1). (Benson 2012 character 50)

306. Prefrontal, ventral process: transversely narrow edge [‘tongue-like’] (0); expanded medially forming antorbital buttress (1). (Benson 2012 character 55)

307. Frontal width:length ratio: <1, frontal narrow (0); >1.5, frontal transversely broad (1). (Benson 2012 character 57)

308. Frontal, anterior process: width equal to that of posterior process (0); narrower than posterior process (1). (Benson 2012 character 58)

309. Postorbital-postfrontal contact: overall trend approximately straight (0); incised by postorbital (1). (Benson 2012 character 63)

310. Postorbital and jugal, medial orbital process (deep, dorsoventrally tall medial flange): absent (0); present (1). (Benson 2012 character 70)

311. Parietal, raised rim around pineal foramen: absent (0); surrounded by raised area forming a pineal ‘ridge’ or boss (1). (Benson 2012 character 83)

312. Stapes, shaft: rod-like, quadrate process small or indistinct (0); blade-like with prominent quadrate process, substantially longer than dorsal process (1). (Benson 2012 character 94)

313. Basioccipital, ventral surface anterior to occipital condyle: smooth (0); prominent anteroposterior ridges (1) (Benson 2012 character 99)

314. Basal articulation [basicranial joint]: present (0); absent (1). (Benson 2012 character 100)

315. Basal articulation, morphology of articular surface of basipterygoid process: single, rounded articular surface (0); flat anterior facet (1); inapplicable, basal articulation absent (-) (Benson 2012 character 103)

316. Parasphenoid body, posteroventral emargination [basisphenoid shelf]: absent (0); present (1). (Benson 2012 character 107)

317. Vomer, internarial shape: widest posteriorly (0); widest near middle (1). (Benson 2012 character 113)

318. Pterygoid, teeth in anterolaterally oriented field: present, extends posteromedially to basicranial area (0); does not extend as far as basicranial area (1); pterygoid heavily denticulated, forming ‘tooth plates’ (2); anterolateral field absent (3) (Modified from Benson 2012 character 122; inapplicability no long an issue as pterygoid tooth characters are separated by field)

319. Dentary: caniniform teeth absent (0); caniniform region present anteriorly (1); Single caniniform tooth present anteriorly (2) (Modesto et al 2014, Character 5)

320. Dentary, mesialmost tooth: not enlarged (0); enlarged (1). (Benson 2012 character 136)

321. Angular, reflected lamina, posterior emargination: short (0); long with free posterodorsal margin (1); inapplicable, reflected lamina absent (-). (Benson 2012 character 144)

322. Cervical vertebrae, count: 3 or fewer (0); 5 or more (1). (Benson 2012 character 149)

323. Presacral/sacral vertebrae, intercentra: present along entire series (0); present only in parts of series, cartilaginous intercentra may be present in places (1); absent (2). (Benson 2012 character 157)

324. Dorsal transverse process, location: approximately at midlength of neural arch, anterior centrodiapophyseal lamina oriented anteroventrally (0); located anteriorly, anterior centrodiapophyseal lamina vertical (1). (Benson 2012 character 159)

325. Dorsal prezygapophyses: planar, do not contact on midline (0); transversely concave, contact on midline (1); planar and inclined strongly medially, contact on midline (2). (Benson 2012 character 160)

326. Dorsal postzygapophyses, hyposphene: absent (0); present and prominent (1). (Benson 2012 character 162)

327. Dorsal and sacral neural spines, dorsal end: unexpanded (0); transversely expanded forming spine table (1). (Benson 2012 character 166)

328. Dorsal ribs, tuberculum (contacts diapophysis) morphology: well-developed and flange-like (0); reduced to low tuberosity (1); low tuberculum with expanded, concave, cup-like articular facet (2) (Benson 2012 character 171)

329. Sacral and caudal neural spines: smooth (0); rugose with longitudinal ridges on lateral surface and tapering apex [‘leaf-shaped’] (1). (Benson 2012 character 17)

330. Scapulocoracoid, glenoid shape: anteroposteriorly elongate and helical (0); short, faces posterolaterally (1). (Benson 2012 character 175)

331. Scapula, anteroposterior breadth of distal end: broad (0); narrow (1). (Benson 2012 character 176)

332. Scapula, anteroposterior breadth of proximal end (base): broad (0); pinched/narrow (1). (Benson 2012 character 177)

333. Scapula, posterolateral surface of blade immediately dorsal to glenoid: weakly concave (0); deep, triangular concavity bounded anteriorly by prominent supraglenoid buttress (1); distinct supraglenoid buttress absent (2) (Benson 2012 character 178)

334. Scapula, location of supraglenoid foramen: immediately dorsal to glenoid (0); 1/3–1/4 blade height dorsal to glenoid (1); inapplicable, supraglenoid foramen absent (-) (Benson 2012 character 181)

335. Scapula, deep notch in anterior margin around midheight: absent (0); present (1). (Benson 2012 character 182)

336. Coracoid, foramen on posterodorsal surface between glenoid and triceps process: absent (0); present (1). (Benson 2012 character 185)

337. Interclavicle, angle of head: low angle, interclavicle weakly curved in lateral view (0); head sharply upturned (1). (Benson 2012 character 189)

338. Interclavicle, shape of posterior margin of head: distinctly offset from shaft by posterolateral emargination (0); grades gradually into shaft (1). (Benson 2012 character 191)

339. Humerus, ventral surface of proximal end: extends proximally forming a low, anteroposteriorly oriented crest posteroventral to head (0); extends far proximally, forming a prominent crest (1). (Benson 2012 character 193)

340. Humerus, anterior surface of deltopectoral crest: weakly concave (0); strongly concave, bounded dorsally by a prominent, proximodistally elongate ridge (1). (Benson 2012 character 194)

341. Humerus, position of latissimus dorsi attachment (Romer and Price 1940, fig. 29): proximal, adjacent to internal epicondyle (0); distal (1). (Benson 2012 character 195)

342. Humerus, morphology of latissimus dorsi attachment: step-like transverse ridge or mound (0); prominent, posteriorly-directed tubercle (1). (Benson 2012 character 196)

343. Humerus, posterior surface of shaft around exit of entepicondylar foramen: convex (0); exit foramen very large and rimmed by a longitudinal depression, foramen only enclosed by a narrow strip of bone (1). (Benson 2012 character 197)

344. Humerus, ventral surface (faces anteroventrally) of entepicondyle: flat or weakly convex (0); low, anteroproximally directed ridge on posterior margin (1). (Benson 2012 character 200)

345. Manus, preaxial (lateral) centrale overlaps proximal surface of third distal carpal: no (0); yes (1). (Benson 2012 character 202)

346. Manus, intermedium size: larger than medial centrale (0); smaller than medial centrale (1). (Benson 2012 character 203)

347. Manus, metapodial shape: long and slender, two–three times longer than maximal width (0); short and fat with small diaphysis (1). (Benson 2012 character 206)

348. Manus, digital formula: X3YZ3 (0); X2YZ2 (1). (Benson 2012 character 208)

349. Manus, phalanges in digit III: four (0); three (1). (Benson 2012 character 209)

350. Manus, phalanges in digit IV: five (0); four or fewer (1). (Benson 2012 character 210)

351. Manus, phalanges, distal articular surface orientation: distal (0); ventrodistal (1). (Benson 2012 character 211)

352. Manus, ungual phalanges, flexor tubercle: single bulbous eminence (0); paired, medial and lateral eminences (1); absent (2). (Benson 2012 character 213)

353. Pubis, midline symphysial contact: enlarged, dorsoventrally broad (0); subequal to height of ischial midline symphysis, restricted to peripheral margin of medial surface (1) (Benson 2012 character 220)

354. Ischium, dorsal margin of medial surface: smooth (0); longitudinal crest (1). (Benson 2012 character 223)

355. Femur, orientation of head: terminal and anteroposteriorly elongate (0); inflected medially and subsherical (1). (Benson 2012 character 225)

356. Femur, greater trochanter: absent (0); present (1). (Benson 2012 character 226)

357. Femur, mound-like eminence on dorsal surface of proximal end: extensive, prominent and longitudinally elongate (0); small (1). (Benson 2012 character 227)

358. Femur, intertrochanteric fossa: prominent (0); reduced or absent (1). (Benson 2012 character 229)

359. Femur, posterior longitudinal ridge located proximally on ventral surface: absent, internal fossa not enclosed posteriorly (0); present, enclosing posterior margin of internal fossa (1). (Benson 2012 character 230)

360. Femur, prominent longitudinal ridge extending posterodistally from distal end of internal fossa: absent or low (0); present as a prominent rugose crest (1); present as a prominent angular ridge forming the posteroventral surface of femoral shaft (2); present but low and does not extend far distally, instead forming a distinct fourth trochanter (3). (Benson 2012 character 231)

361. Femur, posterior condyle, dorsal surface: convex (0); transversely concave, bearing longitudinal trough (1). (Benson 2012 character 234)

362. Astragalus, orientation of tibial articular suface: mediodistal (0); anterodorsal (1). (Benson 2012 character 237)

363. Maxillary teeth, distal recurvature: present (0); absent (1) (NEW)

364. Maxillary teeth, serrations on crown of marginal teeth: absent (0); present (1) (NEW)

365. Maxillary teeth, lateral compression of marginal dentition: only apicially or nowhere (0); over two-thirds of tooth (1) (NEW)

366. Maxillary dentition lingual heel: 0) absent; 1) present (NEW)