SUPPLEMENTARY DATA FOR:

A new selenosteid arthrodire (‘Placodermi’) from the Late Devonian of Morocco

MARTIN RÜCKLIN,^{*,1,†} JOHN A. LONG,^{2,3,4} and KATE TRINAJSTIC^{5,6}

¹School of Earth Sciences, University of Bristol, Wills Memorial building, Queens Road, BS8 1RJ, Bristol, United Kingdom, Martin.Rucklin@naturalis.nl;

² School of Biological Sciences, Flinders University, POB 2100, Adelaide, South Australia, Australia, 5001; john.long@flinders.edu.au;

³ Natural History Museum of Los Angeles County, 900 Exposition Blvd, Los Angeles, CA 9007, U.S.A.;

⁴ Research School of Earth Sciences, Australian National University, Canberra, Australia 0200;

⁵ Western Australian Organic and Isotope Geochemistry Centre, Department of Applied Chemistry, Curtin University of Technology, Bentley, Western Australia, Australia 6845, K.Trinajstic@curtin.edu.au;

⁶ Earth and Planetary Science, Western Australian Museum, Francis St, Perth, Western Australia, Australia 6000

*Corresponding author.

†Current address: Naturalis Biodiversity Center, 2300 RA Leiden, The Netherlands

Description of characters used in phylogenetic analysis. Descriptions (1-85) from Carr (1991), descriptions 23, 29, 31, 75, 79 and 82 modified by Carr and Hlavin (2010) and newly added characters (86-98) by Carr and Hlavin (2010).

Skull roof

- (1) Nuchal plate with posterodorsally placed paired pits (f.lv of Goujet, 1984): absent (0); present (1).
- (2) Posterolateral extension of the lateral consolidated arch: extends as a distinct ridge or thickening onto postmarginal plate, or to the skull roof edge if the postmarginal plate is absent (0); present (1).
- (3) Triangular depression posterior to supraorbital vault (character 14, in part, of Dennis and Miles, 1979b): absent (0); present (1).
- (4) Neurocranial process or thickening (character 16, in part, of Dennis and Miles, 1979b): absent (0); thickening (1); distinct process (2).
- (5) Rostral plate posterior development: not developed (0); subtriangular (1); T-shaped (2).
- (6) Anterior elongation of the rostrum (Dennis and Miles, 1979b:fig. 18, character 3, in part; Long, 1988:characters 4, 12, and 16): absent (0); present (1).
- (7) Ventrally enclosed tubular rostrum: absent (0); present (1).
- (8) Position of anterior edge of pineal plate: over orbit (0); anterior to orbit (1).
- (9) Position of posterior edge of pineal plate: over orbit (0); posterior to orbit (1).
- (10) Shape of the external anterior nuchal border: straight (0); convex (1); concave (2).
- (11) Shape of the posterior nuchal border: straight (0); convex (1); concave (2).

APPENDIX 1. (Continued).

- (12) Nuchal thickening (Lelièvre, 1988): discontinuous with the lateral thickening associated with the craniothoracic dermal articulation (0); continuous thickening across the posterior skull roof (1).
- (13) Preorbital plate embayment of the central plate: absent (0); shallow (1); developed (2).
- (14) Paranuchal plate embayment of the central plate: absent (0); shallow, determined by formation of the lateral lobe, and not the posterior lobe (1); developed as deep embayment, determined by formation of the lateral and posterior lobe (2).
- (15) Ratio for the external longitudinal lengths of the preorbital and central plates ($r = \text{PrO/C}$): subequal, i.e., $0.75 < r < 1.25$ (0); preorbital plate longer, i.e., $r > 1.25$ (1); central plate longer, i.e., $r < 0.75$ (2).
- (16) Postnasal plate infrafenestral process (Gardiner and Miles, 1990: character 22.18): absent (0); present (1).
- (17) Preorbital plate with a dermal preorbital lamina or process (Dennis and Miles, 1979b: character 19): absent (0); present (1).
- (18) Preorbital plates with a median contact (Young, 1981: modified after character 19a): contact posterior to pineal (0); contact anterior to pineal (1); pineal separates preorbital plates (2).
- (19) Extent of median preorbital plate contact: short (0); long, measured as the ratio of (contact length)/(PrO parasagittal length) (1).
- (20) Postorbital plate embayment of the central plate: absent (0); shallow (1); developed as deep embayment (2).
- 21) Length of central plate contact with the nuchal plate: short (0); long, measured as greater than one half the length from the nuchal anteromedian point to the

APPENDIX 1. (Continued).

(posterolateral corner of the nuchal plate (1).

(22) Width of the central plate at its contact with the pineal plate: central plate tapers anteriorly to contact (0); central plate expanded laterally to produce a transverse anterior border (1).

(23) Marginal plate in contact with the central plate (character 5 of Lelièvre, 1988, modified by Carr and Hlavin, 2010): absent (0); present (1).

(24) Extent of marginal plate along the lateral border of the skull roof: less than half the length from the postorbital process to the posterolateral corner of the skull roof (0); greater than half the length (1).

(25) Marginal plate forms part of orbit border (Dennis and Miles, 1979b:character 26): absent (0); present (1).

(26) Postnasal plate forms part of the orbit border (Dennis and Miles, 1979b:fig. 18, character 1): absent (0); present (1).

(27) Extent of postnasal involvement in the orbit border: minimal (0); developed (1).

(28) Orbit size: measured as a ratio of (distance between preorbital and postorbital dermal processes)/(distance between pineal and paired condyles): small (0); intermediate (1); large (2).

(29) Nuchal and paranuchal plates elongate (Lelièvre, 1984b): absent (0); present, associated with an elongation of the endolymphatic canal (1), modified by Carr and Hlavin (2010).

(30) Postnuchal process of paranuchal plate on dermal surface (Dennis and Miles, 1979b: modified after character 8): absent (0); present (1).

(31) Position of the central/paranuchal/marginal or postorbital triple point (plate junction) relative to the paranuchal/central/nuchal triple point: C/PNu/M or PtO triple

point anterior to PNu/ C/Nu (0); posterior to PNu/C/Nu (1), modified by Carr and Hlavin (2010).

(32) Position of preorbital/postorbital/central triple point relative to posterior triple point (PtO/M/C or PtO/PNu/C): parallels the midline or with the anterior point lateral (0); posterior point lateral to anterior point (1).

(33) Position of the PrO/PtO/C triple point relative to the orbit: posterior to orbit (0); over the orbit (1).

(34) Postorbital dermal process; negligible or absent (0); present (1).

Thoracic armour

(35) Median dorsal plate with a ventral ridge (Dennis and Miles, 1979a: combination of characters 4 and 18): a ventral thickening or ridge (0); posterior ridge with a posterior process, not spatulate (1); posterior process posterodorsally spatulate (2).

(36) Median dorsal plate shape (width/length): short and broad to equidimensional (0); body of plate long and narrow, not including a posteriorly produced spine (1).

(37) Median dorsal plate posterior border (Dennis and Miles, 1979a: character 18): rounded (0); spinous (1).

(38) Anterior lateral plate/anterior ventrolateral plate contact: absent (0); present (1).

(39) Anterior lateral plate/interolateral plate external contact: absent (0); present (1).

(40) Interolateral/spinal lateral contact: absent (0); present (1).

(41) Pectoral dermal enclosure: fenestra (0); embayment open posteriorly (1).

(42) Posterior lateral plate and posterior dorsolateral plate overlap (Vézina, 1988): simple overlap (0); insertion (1).

APPENDIX 1. (Continued).

(43) Posterior lateral plate forms part of closed pectoral fenestra: absent (0); present (1).

(44) Posterior lateral plate ventral lamina (Gardiner & Miles, 1990: character 22.13): absent (0); present (1).

(45) Spinal plate (Stensiö, 1959): absent (0); present (1).

(46) Spinal plate spinal pit (Gardiner and Miles, 1990: character 22.32): absent (0); present (1).

(47) Interolateral plate branchial lamina: absent (0); present (1).

(48) Interolateral plate ventral lamina: small or absent (0); developed with either an enlarged contact with the anterior median ventral plate, or an enlarged overlap with the anterior ventrolateral plate (1).

(49) Interolateral plate branchial lamina ornamentation: absent (0); present (1).

(50) Posterior ventrolateral plate dorsolateral contact with the lateral thoracic armor: posterior lateral plate only (0); posterior lateral and anterior lateral plates (1).

(51) Posterior ventrolateral plate postpectoral lamina (Gardiner and Miles, 1990: character 22.8): absent (0); small (1); large (2).

Cheek and palatoquadrate

(52) Suborbital dermal lamina (Dennis and Miles, 1979a: character 17): absent (0); present (1).

(53) Suborbital plate overlaps postorbital plate (Gardiner and Miles, 1990: character 22.9): absent (0); present (1).

(54) Suborbital/preorbital contact: absent (0); lateral contact (1).

APPENDIX 1. (Continued).

- (55) Suborbital and marginal plates in contact (Gardiner and Miles, 1990: character 22.28): absent (0); present (1).
- (56) Suborbital plate with a contact face for the PSG (cf.PSG) on the linguiform process (cr.lg): absent (0); present (1).
- (57) Palatoquadrate ossification (Dennis and Miles, 1979a: character 21): ossified as a single unit (0); autopalatine and quadrate ossifications (1).
- (58) Detent process on quadrate (Gardiner and Miles, 1990: character 22.1): absent (0); present (1).
- (59) Submarginal plate closely associated with the hyomandibular: absent (0); present, indicated by the presence of perichondral bone or the presence of an internal depression (1).
- (60) Form of the submarginal plate: broad (0); elongate (1).
- (61) Length of cheek and skull roof contact: long (0); short, measured as the contact being less than one third of the length measured from the anterior suborbital plate to the posterior cheek/skull roof contact (1).
- (62) Development of cheek/skull roof overlap: loose contact (0); well bound contact, indicated by the interdigitation of plates or their complete fusion (1).

Parasphenoid and gnathal elements

- (63) Inferognathal with a developed blade portion (Dennis and Miles, 1979a: modified after character 13): absent (0); present (1).
- (64) Inferognathal anterior dental field developed anteriorly of the cusp region: absent (0); present (1), indicated by a projection of the inferognathal anterior to the dorsal functional region.

APPENDIX 1. (Continued).

- (65) Adsymphyseal (anterior dental field) denticles: absent (0); present (1).
- (66) Anterior superognathal cusps: none (0); lateral (1); lateral and anterior (2).
- (67) Anterior superognathal plate with an enclosed lateral face: absent (0); present (1).
- (68) Anterior superognathal plate with a dorsal process (Dennis and Miles, 1979a: character 22, in part): absent (0); present (1).
- (69) Dorsal process of the anterior superognathal plate forms an open ring (Lelièvre et al., 1981: modified after character 4): ring open, measured as greater than 90 ° (0); ring forms a ~90 ° angle (1); ring closed, measured angle less than 90 ° (2).
- (70) Posterior superognathal plate with a dorsal process (Dennis and Miles, 1979a: character 22, in part): absent (0); large (1); small (2).
- (71) Width/length ratio for the parasphenoid pre- and posthypophysial shelf: prehypophysial shelf width greater than length, posthypophysial shelf width greater than length (0); prehypophysial shelf width less than length, posthypophysial shelf width greater than length (1); prehypophysial shelf width greater than length, posthypophysial shelf width less than length (2); prehypophysial shelf width less than length, posthypophysial shelf width less than length (3).
- (72) Parasphenoid posterolateral process (Gardiner and Miles, 1990: character 22.36): absent (0); present (1).
- (73) Median hypophysial vein foramen (Gardiner and Miles, 1990: character 22.7): absent (0); present (1).
- (74) Parasphenoid ventromedian crest (Gardiner and Miles, 1990: character 22.27): absent (0); present (1).

APPENDIX 1. (Continued).

Sensory canal grooves

(75) Angle between the postorbital and otic branches of the infraorbital sensory line groove (modified after character 5 of Lelièvre et al., 1987): open posteriorly (i.e., the formed angle is greater than 90 °) (0); partially closed (i.e., the formed angle is between 45 ° and 90 °) (1); closed (i.e., the formed angle is less than 45 °) (2).

Character diagnosis modified by Carr and Hlavin (2010).

(76) Central canal groove meets supraorbital groove: absent (0); present (1).

(77) Ventral groove of the main lateral line on the anterior dorsolateral plate (lc.vl of Miles, 1971:fig. 108): absent (0); present (1).

(78) Dorsal groove of the main lateral line on the posterior dorsolateral plate (Miles, 1971: ld, fig. 108): absent (0); present (1), distinguished from the main lateral line groove by its dorsal trajectory or its continuation onto the median dorsal plate.

(79) Main lateral line groove on the posterior dorsolateral plate (lc of Miles, 1971, fig. 108): absent (0); present (1).

(80) Dorsal groove of the main lateral line on the median dorsal plate (Miles, 1971: ld, fig. 108): absent (0); present (1).

(81) Postorbital sensory line groove on suborbital plate (Lelièvre, 1988:character 1): absent (0); present (1).

(82) Angle between the suborbital and postorbital branches of the infraorbital sensory line groove (Lelièvre, 1984a): opened (0); closed, measured as less than 90 ° (1).

Character diagnosis modified by Carr and Hlavin (2010).

(83) Postorbital branch of the infraorbital sensory line groove and supraoral sensory groove confluent (Lelièvre, 1984a): discontinuous (0); continuous (1).

(84) Supraorbital canal extended onto central plates: absent (0); present (1).

APPENDIX 1. (Continued).

(85) Postmarginal canal: absent (0); present (1).

ADDED CHARACTERS OF CARR & HLAVIN (2010)

(86) Anterior superognathal articulation with parasphenoid (Dunkle and Bungart, 1946): absent (0); present, indicated by either articular facets or a thickened contact face (1).

(87) Parasphenoid anterior contact: thickened anterolateral contact face (0); transverse articular facets (1).

(88) Lateral face of anterior superognathal with an occlusal shelf posterior to the lateral cusp: absent (0); present (1).

(89) Inferognathal with a secondary thickened ridge in the occlusal region, which may be associated with a secondary cusp: absent (0); present (1).

ADDED CHARACTERS OF CARR AND HLAVIN (2010): SKULL ROOF

(90) Skull roof and thoracic armor articulation (Goujet, 1984): articulation medial (0); articulation laterally displaced (1).

(91) Dermal ornamentation: absent (0); present (1).

(92) Position of the posterolateral corner of the skull roof (Long, 1987, character 5).

Alternatively to Long (1987), the ossification center of the marginal plate can serve as a landmark for the posterolateral angle (fig. 8, Carr and Hlavin, 2010). As the anterior landmarks may vary with either snout elongation or orbit enlargement, two landmarks are used; (1) the junction of sensory line grooves for the central and otic and postorbital branches of the infraorbital (csc, ioc.ot, ioc.pt, respectively; fig. 8;

APPENDIX 1. (Continued).

character 92; b; fig. 8), and (2) the pineal aperture or its position beneath the plate (character 93, below; a; fig. 8). Characters 92 and 93 represent independent characters, as the elongation of the anterior skull roof, the enlargement of the orbit, and the shift of the posterolateral corner of the skull roof each represents potentially independent changes to the form of the skull roof. Length ratio ($r1 = b/c$; fig. 8, Carr and Hlavin, 2010) representing the position of the posterolateral corner of the skull roof, measured as the ratio of the anterior sensory line junction–fossa distance (b; fig. 8, Carr and Hlavin, 2010) divided by the posterior sensory line junction–fossa distance (c; fig. 8, Carr and Hlavin, 2010): $r1 < 3.0$ (0); $3.0 \leq r1 \leq 3.9$ (1); $4.0 \leq r1 \leq 6$ (2); $r1 > 7.0$ (3).

(93) Length ratio ($r2 = a/c$; fig. 8, Carr and Hlavin, 2010) representing the position of the corner of the skull roof, measured as the ratio of the pineal foramen–fossa distance (a; fig. 8, Carr and Hlavin, 2010) divided by the posterior sensory line junction–fossa distance (c; fig. 8): $r2 < 3.0$ (0); $3.0 \leq r2 \leq 5.0$ (1); $5.1 \leq r2 \leq 7.5$ (2); $r2 > 7.5$ (3).

(94) In forms with a marginal–central plate contact (e.g., fig. 8, Carr and Hlavin, 2010), position of the junction of the postorbital, marginal, and central plates, relative to the anterior margin of the nuchal plate (modified from Long, 1987, character 7): anterior (0); posterior (1).

(95) In forms with a marginal–central plate contact (e.g. fig. 8, Carr and Hlavin, 2010), position of the junction of the marginal, paranuchal, and central plates, relative to the anterior margin of the nuchal plate (modified from Long, 1987, character 7): anterior (0); posterior (1).

APPENDIX 1. (Continued).

(96) In forms without a marginal–central plate contact, position of the junction between the postorbital, paranuchal, and central plates, relative to the anterior margin of the nuchal plate (modified from Long, 1987, character 7): anterior (0); posterior (1).

(97) Paired pits on the internal side of the nuchal plate (pt.u; fig. 6A, Carr and Hlavin, 2010) separated by a median septum (m.sept; fig. 6A, Carr and Hlavin, 2010) that is continuous with the median posterior process (p.pr; fig. 6A, C): absent (0); present (1).

(98) Presence of a supraorbital vault intimately associated with the lateral consolidated arch (Carr, 1991): absent (0); present (1).