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New decapod crustacean (Brachyura, Raninoida) from the Lower Cretaceous Hudspeth Formation of Oregon, USA

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Abstract

Specimens collected from the Lower Cretaceous (Albian) Hudspeth Formation, Oregon, are referable to *Anoplocarcinus hudspethi* new genus, new species. The new taxon is supported by phylogenetic analysis as well as comparison to type and referred material within Orithopsidae of Raninoida. Albian decapods are rare from the Pacific Coast of North America; this is only the third decapod species reported from the region. Orithopsidae is already well-known from Early Cretaceous occurrences worldwide, and although the new taxon does not extend the geologic range for the family, it expands the biogeographic distribution and morphological diversity among Early Cretaceous orithopsids.

Key words: Orithopsidae, Albian, Necrocarcinoidea, Pacific Coast

Introduction

Raninoida Ahyong *et al*., 2007, and Necrocarcinoidea Förster, 1968, embracing the Orithopsidae Schweitzer *et al*., 2003, have received intensive attention in recent years (Van Bakel *et al*., 2012; Karasawa *et al*., 2014; Schweitzer, Karasawa *et al*., 2016). This scrutiny prompted the reevaluation of specimens from the Albian of Oregon, which were originally referred to *Orithopsis tricarinata* (Bell, 1863) (Vega *et al*., 2010), a species with occurrences in the Albian-Cenomanian of the UK and the Cenomanian of Kazakhstan. A phylogenetic analysis, as well as examination of dorsal and sternal carapace characters, suggest that the specimens are closely related to *Orithopsis* Carter, 1872, but exhibit sufficient differences to warrant proposing a new genus and species. Orithopsidae is already well-known from Pacific coastal North America, represented by *Paradoxicarcinus* Schweitzer *et al*., 2003, from the Santonian of British Columbia, and *Marycarcinus* Schweitzer *et al*., 2003, from the Eocene of Oregon and California.

The occurrence is notable as the only other decapod reported from the Hudspeth Formation is *Eucorystes platys* Schweitzer and Feldmann, 2001. Whereas Albian decapods are abundant in Texas, for example (Rathbun, 1935; Stenzel, 1945; Bishop, 1983; Schweitzer *et al*., 1999; Franțescu, 2013, 2014a, b; Franțescu *et al*., 2016; Schweitzer, Feldmann *et al*., 2016), they are rare on the west coast of North America, including only *Hoploparia tshudyi* Schweitzer and Feldmann, 2001, from Alaska, and *E. platys* from British Columbia (Schweitzer *et al*., 2003). A few Albian occurrences are known from the Western Interior Seaway (Feldmann *et al*., 2008). As Albian rocks are well-reported from other localities worldwide, this occurrence of a new genus on the Pacific Slope of North America is noteworthy.

Phylogenetic Analysis

Schweitzer, Karasawa *et al*. (2016) conducted a

phylogenetic analysis of most taxa within Necrocarcinoidea, resulting in a well-resolved phylogeny. We re-analyzed their matrix adding the character states for the Oregon specimens to ascertain the position of the Hudspeth species. Characters and character states are those used and discussed by Schweitzer, Karasawa *et al.* (2016; tables 1, 2). The Hudspeth species was scored as "1101000010 0?00100000 1111101100 ?1211?0101 010000?110 1?110".

The phylogenetic analysis used PAUP* 4.0b10 (Swofford, 1999), utilizing a data matrix originating in MacClade 4.08 for OS X (Maddison and Maddison, 2005). Heuristic search analyses were performed with the following options in effect: random addition sequence, 1000 replications with random input order; one tree held at each step during stepwise addition; tree-bisection-reconnection (TBR) branch stepping performed; MulTrees option activated; steepest descent option not in effect; branches having maximum length zero collapsed to yield polytomies; topological constraints not enforced; multistate taxa interpreted as polymorphism; character state optimization by accelerated transformation (ACCTRAN).

The analysis yielded six most-parsimonious trees (tree length = 196 steps long with a consistency index (CI) of 0.3878, a retention index (RI) of 0.7906, and a rescaled consistency index (RC) of 0.3085). The relationships among taxa are unchanged except for the addition of the Hudspeth species within Necrocarcinoidea. The Hudspeth species is derived as the sister to *Orithopsis* within Orithopsidae. The Hudspeth species differs from *Orithopsis* in lacking a median ridge, having spines or tubercles on the branchial regions, and lacking complex orbital spines.

Systematic Paleontology

Institutional abbreviations: BMNH, The Natural History Museum, London, UK; CM, Carnegie Museum of Natural History, Pittsburgh, PA, USA; DGEO, Departamento de Geologia, Universidade Federal de Pernambuco, Brazil; GSC, Geological Survey of Canada Eastern Paleontology Division, Ottawa, ON, Canada; IGM, Servicio Geológico Colombiano, Bogotá, Colombia; MGUH, Geologisk Museum University of Copenhagen, Copenhagen, Denmark; SDSNH, San Diego Society of Natural History, San Diego Natural History Museum, San Diego, CA, USA; SM Sedgwick Museum, Cambridge University, Cambridge, UK; TMM NPL, BEG, Texas Memorial Museum, Non-vertebrate Paleontology, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX, USA; USNM, United States National Museum of Natural History, Smithsonian Institution, Washington, DC, USA; UWBM, University of Washington Thomas Burke Memorial Washington State Museum, Seattle, Washington, USA.

Infraorder Brachyura Linnaeus, 1758
Section Raninoida Ahyong Lai, Sharkey, Colgan and Ng, 2007
Superfamily Necrocarcinoidea Förster, 1968

Family Orithopsidae Schweitzer, Feldmann, Fam, Hessin, Hetrick, Nyborg, and Ross, 2003

Included genera: *Aetocarcinus* Schweitzer, Feldmann, Rader, and Franțescu, 2016 (= *Juglocarcinus* Collins *et al.* in Garvie *et al.*, 2017); *Anoplocarcinus* new genus; *Bellcarcinus* Luque, 2014; *Cherpiocarcinus* Marangon and De Angeli, 1997; *Colombicarcinus* Karasawa, Schweitzer, Feldmann, and Luque, 2014; *Cristella* Collins and Rasmussen, 1992; *Exucarcinus* Prado and Luque, *in* Prado *et al.*, 2018; *Marycarcinus* Schweitzer, Feldmann, Fam, Hessin, Hetrick, Nyborg, and Ross, 2003; *Orithopsis* Carter, 1872; *Paradoxilissopsa* Schweitzer, Dworschak, and Martin, 2011 (= *Lissopsis* Frič and Kafka, 1887); *Paradoxicarcinus* Schweitzer, Feldmann, Fam, Hessin, Hetrick, Nyborg, and Ross, 2003; *Planocarcinus* Luque, Feldmann, Schweitzer, Jaramillo, and Cameron, 2012; *Shazella* Collins and Williams, 2004; *Silvacarcinus* Collins and Smith, 1993; *Texicancer* Franțescu, Feldmann, and Schweitzer, 2016.

Diagnosis: Schweitzer, Karasawa *et al.* (2016, p. 355).

Material examined: *Aetocarcinus roddai*: *Diaulax roddai* Bishop, 1983, holotype, SDSNH 23640 and *Pseudonecrocarcinus stenzeli* Bishop, 1983, holotype, SDSNH 23641; TMM NPL 69683–69692, 69725. *Bellcarcinus aptiensis* Luque, 2014, holotype IGM p881107, and paratypes IGM p881154, IGM p881156, and IGM p881166. *Colombicarcinus laevis* Karasawa, Schweitzer, Feldmann, and Luque, 2014, holotype IGM p881167, and paratype IGM p881105.

Cristella hastata Collins and Rasmussen, 1992, cast of holotype MGUH 21.611 numbered KSU 1807. *Exucarcinus gonzagai* Prado and Luque, *in* Prado *et al.* 2018, holotype DGEO-CTG-UFPE-8114, and paratypes DGEO-CTG-UFPE-7745, 7748, 7749, 7751, 8103, 8105, 8107, 8109, 8115, 8116, 8133, 8106. *Planocarcinus olssoni*: *Dakoticancer olssoni* Rathbun, 1937, holotype USNM 495104. *Marycarcinus hannae*: *Necrocarcinus hannae* Rathbun, 1926, CM45974. *Texicancer renfroae*: *Necrocarcinus renfroae* Stenzel, 1945, BEG 21093, holotype, BEG 21094; TMM NPL 69681-69682. *Orithopsis bonneyi* Carter, 1872, holotype SM B 58857. *Orithopsis tricarinata*: *Necrocarcinus tricarinatus* Bell, 1863, paralectotype SM B 23259, B 30733-4. *Paradoxicarcinus*

nimonoides Schweitzer, Feldmann, Fam, Hessin, Hetrick, Nyborg, and Ross, 2003, holotype GSC 124826, and paratype, GSC 124827. *Shazella abbotsensis* Collins and Williams, 2004, holotype, (BMNH) IC. 306.

Discussion: The new taxon displays most of the diagnostic characters of the family, and indeed nested as a derived member of the family in our phylogeny. Sternal elements of the new taxon differ somewhat from that of the other two orithopsid genera for which sterna are known, *Orithopsis* and *Silvacarcinus*. *Orithopsis tricarinata* (Bell, 1863) shares some characteristics with the new taxon, including the wide rim on the concave lateral margins of sternite 4, a deep groove between sternite 4 and its episternites; and sternal suture 4/5 directed posterolaterally (Van Bakel *et al*., 2012, figure 22). The shape of sternite 3 differs between the two taxa; it is longer than wide in *O. tricarinata* and wider than long in the new taxon. The sternum of *Silvacarcinus laurae* Collins and Smith, 1993, has wider, less developed rims on sternite 4 than either *Orithopsis tricarinata* or the new taxon (Van Bakel *et al*., fig. 21). In *S. laurae*, sternal suture 4/5 and 5/6 are directed laterally, whereas those sutures in the new taxa are directed strongly posterolaterally. The groove separating sternite 4 from episternite 4 is weaker in *S. laurae*. Most notably, *S. laurae* has an incomplete suture 5/6, whereas the new taxon appears to have a complete suture 5/6. That suture is unknown in *O. tricarinata*. It is possible that the sternum is simply broken along that margin, but the edges of the somites along suture 5/6 are straight and do not show evidence of breakage. In addition, in *S. laurae*, sternal sutures 7/8 are in contact with each other and sternite 8 appears to be rotated so that it is essentially internal. The new taxon exhibits sternite 7 on both sides, and the margins of these sternites do not meet, suggesting that sternite 8 is not rotated internally, although it is not visible in the new specimen. Sternites 6–7 are strongly deflexed in the new taxon, whereas only 7 is deflexed in *S. laurae*. The new genus possesses a bulge anteriorly and axially on sternite 7, similar to that seen in *S. laurae* (Van Bakel *et al*., 2012, fig. 21F). Thus, although the new genus is similar to other orithopsids in terms of sternal morphology, there are a few notable differences. The variability of sternal suture 5/6 is of some concern, as these sutures usually are conserved within a family. More material could help to determine whether this suture is actually a break in the new taxon or is in fact complete.

The dorsal carapace of the new taxon differs from other members of the family in a few ways. Many orithopsids have very long anterolateral spines, such as *Cristella*, *Paradoxicarcinus*, and *Cherpiocarcinus*; those spines on the new genus are moderately long, more similar to *Exucarcinus*. *Aetocarcinus*, *Marycarcinus*, *Planocarcinus*, and *Shazella* are ornamented with either coarse, sporadic tubercles or uniformly with granules and tubercles. The new taxon lacks coarse granules, and it exhibits only 2 large tubercles on the protogastric region. Most notably, the new taxon has branchial longitudinal keels as is typical of the family but lacks an axial keel, seen in many members of the family, including *Orithopsis*, *Marycarcinus*, *Silvacarcinus*, and *Texicancer*. The new genus is most like *Orithopsis*, but lacks the axial keel and the long orbital spines and rostrum seen in *Orithopsis*. The branchial keels in the new genus are better developed and narrow, whereas they are poorly developed in *O. bonneyi* Carter, 1872, and broad in *O. tricarinata* (Bell, 1862).

***Anoplocarcinus,* new genus**

Type species: *Anoplocarcinus hudspethi* new species, designated herein.

Diagnosis: Carapace wider than long, hexagonal; rostrum not well known, appearing to extend slightly beyond orbits; orbits with two closed fissures and long outer-orbital spine; anterolateral margins with four spines, excluding outer orbital spine, second and third moderately long; protogastric region with two large tubercles; branchial keels slightly oblique, narrow, with a few small scattered tubercles; branchiocardiac and cervical grooves subequal in development; sternal suture 5/6 possibly complete; sternites 7 not in contact along posterior margin; sternites 6 and 7 strongly deflexed.

Etymology: The generic name is derived from the Greek *anoplos*, meaning unarmed, and the stem *-carcinus*, meaning crab, referring to the simple nature of the ornamentation of this taxon. The gender is masculine.

***Anoplocarcinus hudspethi,* new species**

(Figs. 1, 2)

Diagnosis: as for genus.

Description: Carapace wider than long, length 78–86% maximum carapace width; broadly hexagonal, widest 55% the distance posteriorly on carapace; weakly vaulted longitudinally and transversely.

Front not well-preserved, axially broadly sulcate, with two spines marginally serving as inner orbital spines. Orbits directed forward, rectangular, with two closed fissures, outer-orbital spine longer than inner-

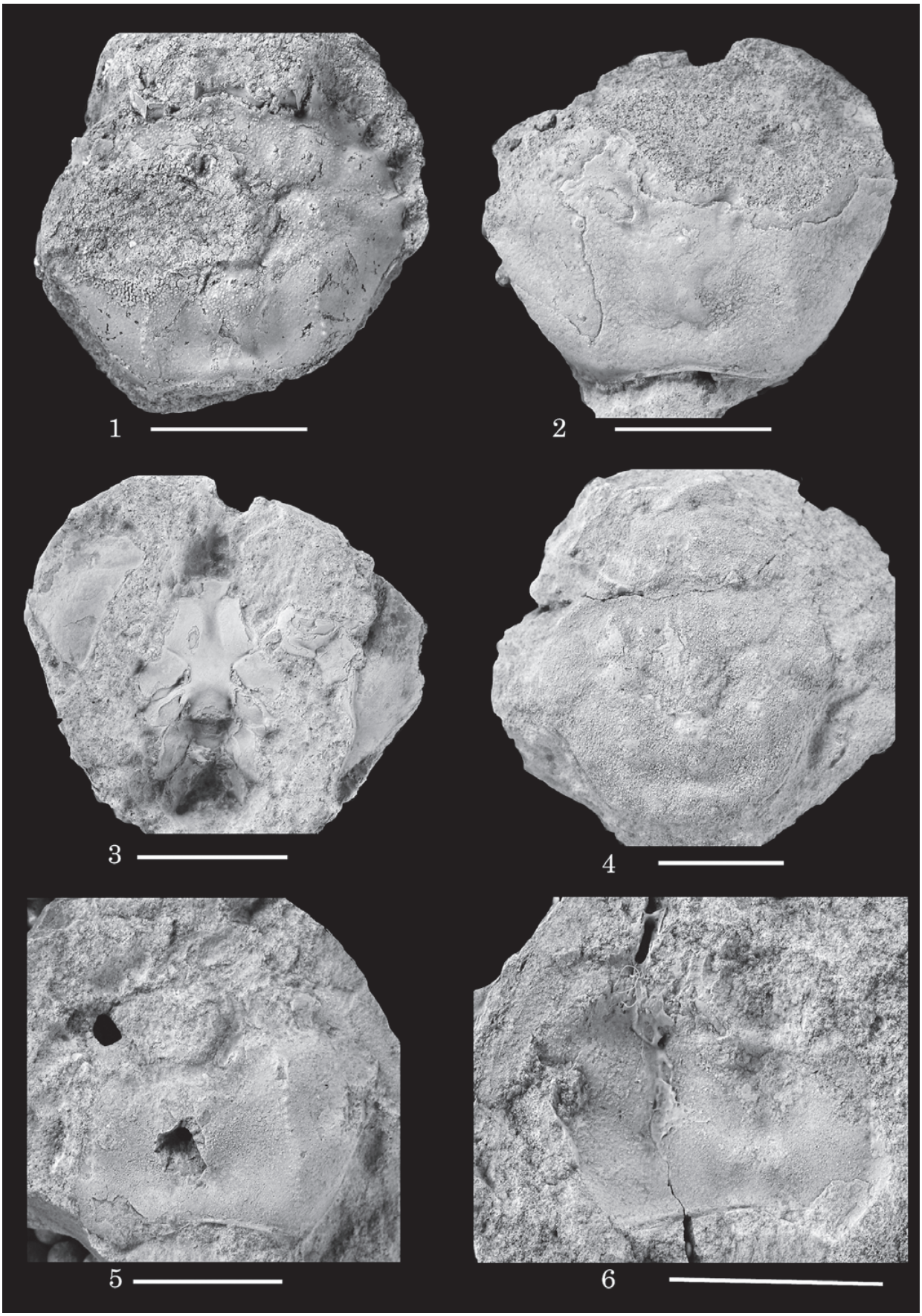

Fig. 1. ***Anoplocarcinus hudspethi,*** **new genus, new species**. *1*, UWBM 98681, holotype, dorsal carapace; *2–3*, UWBM 98678, paratype, partial dorsal carapace (*2*) and sternum (*3*); *4*, UWBM 98679, paratype, dorsal carapace; *5*, UWBM 98682, paratype, partial dorsal carapace; *6*, UWBM 98680, paratype, counterpart of UWBM 98682. Scale bars = 1 cm.

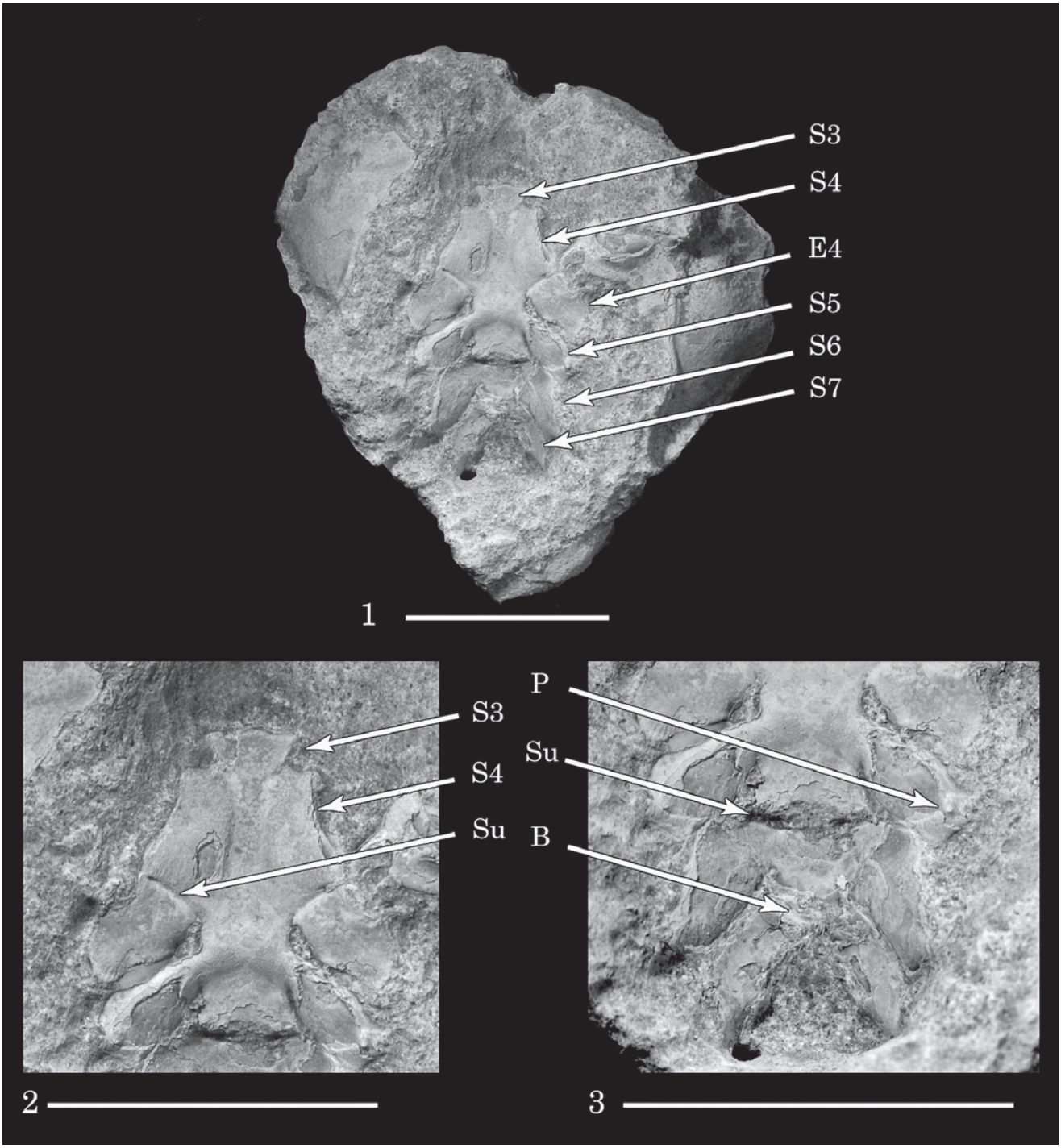

Fig. 2. ***Anoplocarcinus hudspethi,*** **new genus, new species**, UWBM 98678, paratype. *1*, sternum with visible sternites numbered (S3–S7); *2*, anterior portion of sternum with sternites 3 and 4 (S3, S4) and deep suture (Su) between sternite 4 and episternite 4; *3*, posterior portion of sternum indicating paired tubercles on sternite 5 (P); 5, sternal suture 5/6 (Su) and bulge (B) on sternite 7. Scale bars = 1 mm.

orbital spine, orbital margin weakly upturned, fronto-orbital width about half maximum carapace width (Fig. 1.1). Anterolateral margins weakly convex, with four spines excluding outer-orbital spine, spines triangular, short, sharp; spines one through four increasing in size posteriorly (Fig. 1.1). Posterolateral margins weakly sinuous, initially slightly concave, then slightly convex, with one spine just posterior to anterolateral corner, spine about same size as last anterolateral spine. Posterior margin narrower than fronto-orbital width, weakly concave, rimmed.

Mesogastric region with long anterior process, widened posteriorly; metagastric region about same width as mesogastric region, narrowing posteriorly; urogastric region a wide, depressed groove; cardiac region rounded-triangular, apex directed posteriorly,

with three tubercles anteriorly and one tubercle near apex; intestinal region short, flattened; epigastric through cardiac regions raised moderately but lacking a distinct axial carina or keel.

Cervical groove strong axially and posterior to protogastric region, becoming weak laterally; cervical and branchiocardiac more or less parallel to one another, branchiocardiac groove somewhat weaker than cervical groove, best developed laterally; postcervical groove developed as urogastric region; secondary groove anterior to cervical groove arising at about half distance along anterolateral margin, extending straight onto carapace, then making a nearly 90° turn posteriorly to meet cervical groove, secondary groove as deep as or deeper than cervical groove.

Protogastric regions rectangular, moderately inflated, with two large swellings situated transversely centrally. Hepatic region inflated posteriorly, with central swelling, flattened anteriorly, flattened region separated from inflated region by secondary groove. Epibranchial region arcuate, extending from last anterolateral spine to position just lateral to metagastric region, bounded anteriorly by cervical groove and branchiocardiac groove posteriorly, with large swelling just posterior to protogastric region. Remainder of branchial region undifferentiated, with oblique longitudinal keel extending from about level of anterior end of cardiac region to posterolateral corner, with several tubercles (Figs. 1.1, 1.5).

Male (?) sternum longitudinally ovate, broadly concave (Fig. 2); sternite 3 short; sternite 4 trapezoidal, longer than wide, thickened along lateral margins, with short projections extending from anterior end, pereiopod 1 articulating at anterior end of posterolateral projection, suture between sternite 4 and episternite 4 deep (Fig. 2.2); sternal suture 4/5 deep, directed obliquely posterolaterally, becoming straight and oriented parallel to axis of animal axially, not crossing axis; sternite 5 wider than long, with paired tubercles on each side probably serving to hold pleon in place (Fig. 2.3), directed posterolaterally; sternites 5 through 7 inclined at moderate angle to remainder of sternum; sternite six directed posterolaterally, about as wide as long; sternite 7 wider than long, directed strongly posterolaterally, with bulge anterior and axially (Fig. 2.3); sternite 8 unknown; sternal suture 6/7 complete; sternal suture 5/6 may be complete (Fig. 2.3).

Measurements: Measurements, in mm, taken on specimens of *Anoplocarcinus hudspethi* new genus, new species: UWBM 98681 (holotype) and UWBM 98679 (paratype), respectively: maximum carapace length, 18.7, 21.1; maximum carapace width, 24.0, 24.4; fronto-orbital width, 12.1, 11.6; frontal width, 3.9, NA; length from frontal margin to position of maximum width, 10.4, 11.6.

Etymology: The trivial name is derived from the Hudspeth Formation, from which the specimens were collected.

Types: The holotype of *Anoplocarcinus hudspethi* new genus, new species, is UWBM 98681, and paratypes are UWBM 98678–98680, 98682.

Occurrence: The material was collected from the Albian Hudspeth Formation (locality in Vega *et al*., 2010).

Discussion: The specimens here referred to *Anoplocarcinus hudspethi* new genus and species were originally referred to *Orithopsis tricarinata* (Vega *et al*. 2010), along with the holotype of *Planocarcinus olssoni* (Rathbun, 1937), USNM 495104. As discussed above, the new material is referable to a new genus and species within Orithopsidae. Vega *et al*. (2010) illustrated some of the specimens herein comprising the type series of *Anoplocarcinus hudspethi* new genus, new species, in figures 8.18–8.23. Figure 8.18 is designated as UWBM 98678; however, the illustrated specimen is not the one associated with that number. We are unsure as to the whereabouts of that specimen. Figure 8.19 is correctly identified as UWBM 98679, and figures 8.20 and 8.21 are correctly identified as UWBM 98678. Figure 8.22, identified in the caption as UWBM 98678, is actually UWBM 98681. Figure 8.23 is the holotype, USNM 495104, of *Planocarcinus olssoni* (Luque *et al*., 2012). UWBM 98682 and 98680 are part and counterpart, respectively, of the same specimen.

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improved the manuscript.

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Obituary for Joe S. H. Collins

Joe S. H. Collins died peacefully at his home on Friday, January 25, 2019, at the age of 91. His life style was kind and gentle, reminiscent of that which is rarely seen today. Joe began publishing on fossil decapods and barnacles in 1961, and there has been a steady stream of studies up until his death. Remarkably, Joe was working at the Natural History Museum (London) on Thursday, January 24. The primary emphasis of his work was on decapods from England, although he also published on decapods from the Caribbean region in later years. His work invariably was of the highest standard. The monograph, *British Cretaceous Crabs*, published in 1972 and co-authored with C.W. Wright, is a landmark contribution which continues to be cited frequently.

Joe was a long-standing member of The Geologists' Association. In 2010, he received the Harrell L. Strimple Award of the Paleontological Society in recognition of his massive contributions as an "amateur." He will be missed by his many friends and co-authors, not simply as a good scientist but also as a wonderful person.

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