ARCOSCALPELLUM HOEK AND *SOLIDOBALANUS* HOEK (CIRRIPEDIA, THORACICA) FROM THE PALEOGENE OF PACIFIC COUNTY, WASHINGTON, WITH A DESCRIPTION OF A NEW SPECIES OF *ARCOSCALPELLUM*[1]

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ABSTRACT. *Arcoscalpellum raricostatum* Withers, 1953, previously known from the Italian and Cuban Eocene, and *A. knapptonensis* n. sp. occur in concretions in the basal beds of a chronostratigraphic equivalent of the Lincoln Creek Formation exposed along the Columbia River near Knappton, Pacific County, Washington. The middle units have yielded only fragmentary arcoscalpellid remains. The upper beds contain a species of *Solidobalanus* Hoek, 1913, similar to *S.* (*Hesperibalanus*) *sookensis* (Cornwall, 1927) from the Sooke Formation (Juanian Molluscan Stage) of Vancouver Island, British Columbia. The molluscan faunas of the middle and upper beds are characteristic of the Matlockian and Juanian Molluscan Stages, respectively (Zemorrian benthic Foraminiferal Stage, or Oligocene). Molluscs are not known from the basal unit, but the arcoscalpellids suggest a late Eocene age (Galvinian Molluscan or Refugian benthic Foraminiferal Stage) based on their affinities with late Eocene European species. The two species of *Arcoscalpellum* Hoek, 1907, are the first scalpelloid barnacles to be reported from the Pacific Coast Cenozoic.

INTRODUCTION

Calcareous concretions from marine sediments exposed along the north shore of the Columbia River near Knappton, Pacific County, Washington (Figure 1) contain numerous, well-preserved, but disarticulated capitular plates of two species of *Arcoscalpellum* Hoek, 1907, and the shells and a few opercular plates of an archaeobalanid resembling *Solidobalanus* (*Hesperibalanus*) *sookensis* (Cornwall, 1927). The arcoscalpellids are the first scalpelloid barnacles to be recorded from the Pacific Coast of North America. *Arcoscalpellum* in the traditional sense is an extant, cosmopolitan genus with a fossil record extending back to the Late Cretaceous. It is represented by more than 100 extant species found primarily at bathyal and abyssal depths, and by over 50 fossil species from Upper Cretaceous and Tertiary inshore shelf deposits. Nine fossil species have been reported from North America. As many have perceived, the traditional conception of the genus *Arcoscalpellum* includes a diversity of species whose relationships are not altogether clear. Several attempts have been made to isolate species-groups within the genus, but only Zevina (1978) has proffered a comprehensive revision of the extant species. In Zevina's classification, the species of *Arcoscalpellum,* together with those of *Holoscalpellum* Pilsbry, 1907, are distributed among 12 genera in the subfamily Arcoscalpellinae Zevina. No attempt has yet been made to reevaluate the classification of fossil species in light of Zevina's revision. This may not be possible for many fossil species, because generic assignment in Zevina's scheme is dependent upon knowledge of the total armature of the capitulum, and many fossil species are known only from a few disarticulated capitular plates. Buckeridge (1980) has proposed a new genus for a group of Tertiary species from Australasia characterized by heavily calcified capitular plates and an absence of pits on the interior of the scutum for the placement of males. The classificatory significance of these features and their distribution in fossil and extant species outside of the Australasian region are unknown.

Archaeobalanids are the oldest known balanoid barnacles, first appearing in middle Eocene rocks, and are the most commonly encountered balanoids in Paleogene deposits. Three fossil species have been described from the Pacific Coast Tertiary: *Solidobalanus* (*Hesperibalanus*) *cornwalli* (Zullo, 1966) from the middle or upper Eocene Cowlitz Formation of Lewis County, Washington; *S.* (*H.*) *sookensis* from the Oligocene Sooke Formation of Vancouver Island, British Columbia; and *S.* (*H.*) *proinus* (Woodring, 1950) from the Pliocene of central and southern California (Zullo, 1979a). The extant North Pacific species, *S.* (*H.*) *hesperius* (Pilsbry, 1916), is common in Pleistocene deposits of the Pacific Northwest. *Hesperibalanus* Pilsbry, 1916, was synonymized with *Solidobalanus* Hoek, 1913, by Henry and McLaughlin (1967) but was reinstated as a subgenus of *Solidobalanus* by Newman and Ross (1976). Of the four extant and nine extinct species presently included in *Hesperibalanus,* only two, *S.* (*H.*) *hesperius* and *S.* (*H.*) *proinus,* can be ascribed to this subgenus with certainty. The remainder are included presently as a matter of convenience, awaiting a much needed revision of the free-living Archaeobalaninae.

The Knappton Cirripedia are significant in several respects. The presence of arcoscalpellids extends the known Paleogene

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distribution of this group into the northeastern Pacific. The occurrence of archaeobalanids supports previous indications that free-living members of this group are widespread in Paleogene deposits (Zullo and Baum, 1979). Perhaps most importantly, the Knappton species suggest that cirripeds are useful biostratigraphic indicators, discussion of which follows the systematic account.

STRATIGRAPHY OF THE KNAPPTON EXPOSURES

The Knappton beds are considered chronostratigraphic equivalents of the Lincoln Creek Formation of Beikman and others (1967) (replacement name for the Lincoln Formation of Weaver, 1912, and of subsequent authors). In the Grays Harbor basin located northeast of the Knappton locality, the Lincoln Creek Formation consists of up to 2,740 m of tuffaceous siltstone and sandstone containing scattered concretions and concretionary beds. The Lincoln Creek Formation is considered to range from the late Eocene to earliest Miocene (Rau, 1958, 1964; Armentrout, 1975, 1977). The lower part of the formation is correlated with the Keasey Formation of Oregon and the Toutle Formation (Gries Ranch beds) of southern Lewis County, Washington. The upper part of the formation is equivalent to the Sooke Formation of Vancouver Island, British Columbia, and the upper part of the Twin River Formation of Washington (Armentrout, 1977).

According to Ray Wells (personal communication, 1980), who has mapped the region and measured and described the section, much of the Knappton section is covered, including the contacts with under- and overlying units. That part of the section considered correlative with the Lincoln Creek Formation consists of about 305 m of thin-bedded and laminated tuffaceous siltstone and sandy siltstone bearing occasional concretions, some of which are several meters in length. This unit is overlain by at least 150 m of concretionary sandstone, sandy siltstone, and siltstone that is equivalent to the Miocene Astoria Formation of western Oregon. The underlying unit is not exposed. Fossils from the Knappton exposures, including those described here, were collected by James and Gail Goedert, who divided the "Lincoln Creek" part of the section into four informal faunistic units (Figure 2): (1) a lower unit characterized by barnacle-bearing concretions and an abundance of the trace fossil *Tisoa* De Serres; (2) an overlying unit containing tisoans, sponges, small aturiid nautiloids, and many decapod crustacean and marine vertebrate remains; (3) a glass sponge zone; and (4) an upper unit characterized by an abundance of invertebrate and marine vertebrate remains, including large aturiid nautiloids, but with few sponges and no tisoans. Frey and Cowles (1969, 1972) reported on the single, double, U-shaped, and branching burrows of *Tisoa* from the Knappton locality (primarily unit 1) and noted the presence of the decapod crustacean *Callianassa knapptonensis* Rathbun, 1926, based on a record in Weaver (1942). Armentrout (personal communication, 1979) refers the molluscan fauna of unit 2 to the *Echinophoria rex* zone (= Matlockian Molluscan Stage, = lower Zemorrian benthic Foraminiferal Stage, = lower Oligocene), and that of unit 4 to the *Echinophoria apta* zone (= Juanian Molluscan Stage, = upper Zemorrian benthic Foraminiferal Stage, = upper Oligocene).

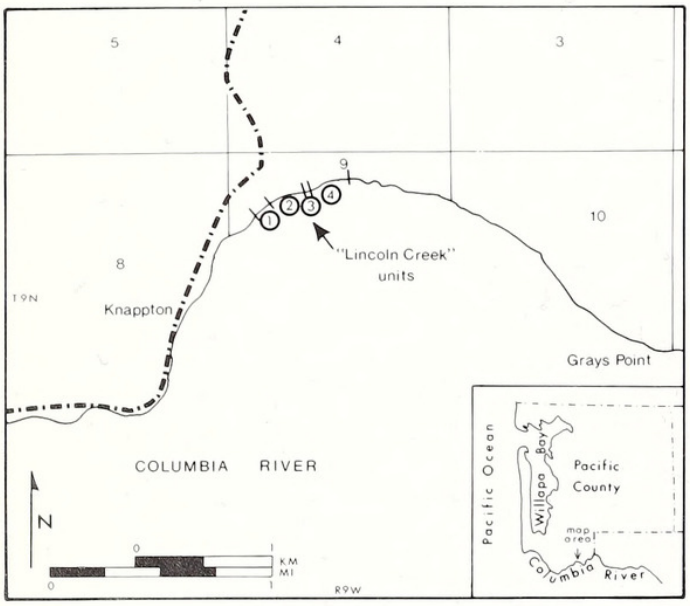


Figure 1. Part of the Knappton, Washington 7.5-minute quadrangle showing location of "Lincoln Creek" faunal units. Inset map shows location of Knappton quadrangle in Pacific County.

CIRRIPED BIOSTRATIGRAPHY

The two identifiable arcoscalpellids are from faunal unit 1 (Natural History Museum of Los Angeles County Invertebrate Paleontology, LACMIP, locality 5844). A new species of *Arcoscalpellum* (?strict sense), represented by numerous carinae, scuta, and terga, is most similar to *A. gassinensis* (de Alessandri, 1906) from the Eocene Calcare di Gassino on the Bussolino side of Gassino, northeast of Turin, Italy. The second species, represented by partial carinae, is ascribed to *A. raricostatum* Withers, 1953, also described from the Calcare di Gassino near Bussolino. Withers (1953, p. 59) considered the Calcare di Gassino to be Auversian and middle Eocene, and correlative with the Upper Bracklesham beds at Whitecliff Bay, Isle of Wight. Withers's age determination appears to be based on the occurrence of *Nummulites variolarius* (Lamarck) in both units. Herb and Hekel (1973), among others, have shown that *N. variolarius* first appears in the uppermost middle Eocene (Biarritzian) but continues throughout the upper Eocene (Bartonian/Priabonian) in many parts of Europe, including northern Italy. In addition to the current practice of considering the Auversian as basal upper Eocene, Cita (1973), in a review of the Tertiary strata of the Italian Piedmont, regarded the Calcare di Gassino as Priabonian. Thus, it would appear that *Arcoscalpellum gassinensis* and *A. raricostatum* are upper rather than middle Eocene species.

The two species of *Arcoscalpellum* from the Knappton section thus suggest that the basal part of the exposed "Lincoln Creek" is upper Eocene (= Galvinian Molluscan or Refugian benthic Foraminiferal Stage). This conclusion is supported by the cirriped faunal "facies" of the upper Eocene (Jacksonian Gulf Coastal Plain Stage) Principe Formation in the vicinity of Havana, Cuba. In addition to *A. raricostatum* (see systematic account), this unit contains two other species of *Arcoscalpellum*, *A. habanense* Withers, 1953, and *A. sanchezi* (Withers, 1926), that are closely related both to *A. gassinensis* and the new Knappton species.

It is unfortunate that the only cirriped remains so far recovered from unit 2 (LACMIP locality 5843) are poorly preserved terga. These plates may represent a species of *Arcoscalpellum,* but terga are not sufficient in distinguishing between the *A. gassinensis* complex and the quite distinctive species of the known Oligocene fauna. Knowledge of the identity of this species might prove helpful in determining the age of unit 2. Many European geologists would place the Eocene-Oligocene boundary at the base of the Rupelian (see Withers, 1953; Van Eysinga, 1975). This shift in the boundary relegates the traditional European lower Oligocene Lattorfian and Tongrian Stages to the upper Eocene. The crux of arguments favoring this change is that Lattorfian and Tongrian faunas are more similar to Bartonian/Priabonian faunas than they are to Rupelian faunas. Recognition of upper Eocene equivalents and of the Eocene-Oligocene boundary in North America is further complicated by increasing endemism of invertebrate megafaunas and by apparent disagreement in correlation between upper Eocene calcareous nannofossil and planktonic foraminiferal zones. In addition, there is increasing evidence from potassium-argon, rubidium-strontium, and fission track age determinations in Europe, the Caribbean, and the Atlantic and Gulf Coastal Plains that the Eocene-Oligocene boundary is closer to 33 m.y. than to the 37-m.y. date proposed by Hardenbol and Berggren (1978) (Harris and Zullo, 1980). Those faunas and faunal zones whose ages have been related to radiometric age determinations must be reevaluated in light of this evidence.

Although opercular plates are preserved in some of the archaeobalanid shells from unit 4 (LACMIP locality 5842), the sediment is too well indurated to permit their intact extraction. The shells are quite similar to those of *Solidobalanus sookensis,*

	FORAMINIFERAL STAGES	MOLLUSCAN STAGES	KNAPPTON BEDS	KNAPPTON CIRRIPEDIA
MIOCENE	SAUCESIAN	NEWPORTIAN	"ASTORIA" FM.	
		PILLARIAN	?	
OLIGOCENE	ZEMORRIAN	JUANIAN	UNIT 4 LACMIP 5842	SOLIDOBALANUS AFF. SOOKENSIS
			UNIT 3	
		MATLOCKIAN	UNIT 2 LACMIP 5843	
UPPER EOCENE	REFUGIAN	GALVINIAN	UNIT 1 LACMIP 5844	ARCOSCALPELLUM KNAPPTONENSIS A. RARICOSTATUM
			?	

Figure 2. Stratigraphic distribution of Knappton cirripeds and suggested correlation of the Knappton beds (partly after Armentrout, personal communication, 1979).

but the internal morphology of the single scutum examined is sufficiently different to question assignment of the Knappton specimens to that species without additional opercular plate material. It is clear that the Knappton species is unrelated either to the upper Eocene *S. cornwalli* or to true *Hesperibalanus*. The occurrence of a species of *Solidobalanus* similar to *S. sookensis* in unit 4 is in agreement with the Oligocene age assignment derived from molluscan data.

SYSTEMATIC ACCOUNT

Subclass Cirripedia Burmeister, 1834

Order Thoracica Darwin, 1854

Suborder Lepadomorpha Pilsbry, 1916

Family Scalpellidae Pilsbry, 1916

Subfamily Arcoscalpellinae Zevina, 1978

Genus *Arcoscalpellum* Hoek, 1907

Arcoscalpellum knapptonensis n. sp.

Figures 3–7, 9–17

DIAGNOSIS. Broad, slightly bowed carina with arched tectum, faintly ridged parietes, and very narrow, inwardly turned intraparietes; broad, trapezoidal, longitudinally striate scutum with low, flat, apico-basal ridge and decidedly obtuse basitergal angle; tergum subtriangular, longitudinally striate, twice as long as wide, with acute apico-basal ridge and without marked distinction between upper and lower carinal margins. Distinguished from *A. gassinensis* and *A. habanense* by its narrower carina without conspicuous ridges on or bordering the tectum; from *A. sanchezi* and *A. euglyphum* by its carinal parietes that do not flare outwardly; from *A. choctawensis* and *A. toulmini* by its much broader tergum and thicker capitular plates.

LOCALITY. LACMIP locality 5844, "Lincoln Creek Formation," faunal unit 1, on Columbia River approximately 122 m east of boundary between sections 8 and 9, T 9 N, R 9 W, USGS 7.5-minute topographic quadrangle of Knappton (1973 ed.), near Knappton, Pacific County, Washington.

MATERIAL EXAMINED. Disarticulated carinae, scuta, and terga in four concretions. Holotype (LACMIP no. 6270) and paratypes (LACMIP nos. 6266-6269, 6330-6333) are in the invertebrate paleontology collection of the Natural History Museum of Los Angeles County.

DESCRIPTION. Carina slightly bowed, broad, length about four times width; tectum moderately to strongly arched, flattening towards basal margin, sometimes with incipient medial ridge; basal margin broadly V-shaped; parietes half as wide as tectum, normal to tectum, and separated from tectum by one or two inconspicuous, narrow, longitudinal ridges; parietes ornamented by up to five faint longitudinal ridges; intraparietes very narrow, separated from parietes by narrow but conspicuous ridge, and turned inward at approximately a 45° angle.

Scutum strongly arched, trapezoidal, length less than twice width; apico-basal ridge flat, low, slightly curved; occludent margin slightly convex; basal and lateral margins straight, nearly equal in length, their junction forming an angle greater than 90°; tergal margin concave; tergolateral margin rounded, outer surface ornamented by faint, irregularly placed, longitudinal striae best developed on tergal side of plate; adductor muscle pit shallow, ill-defined.

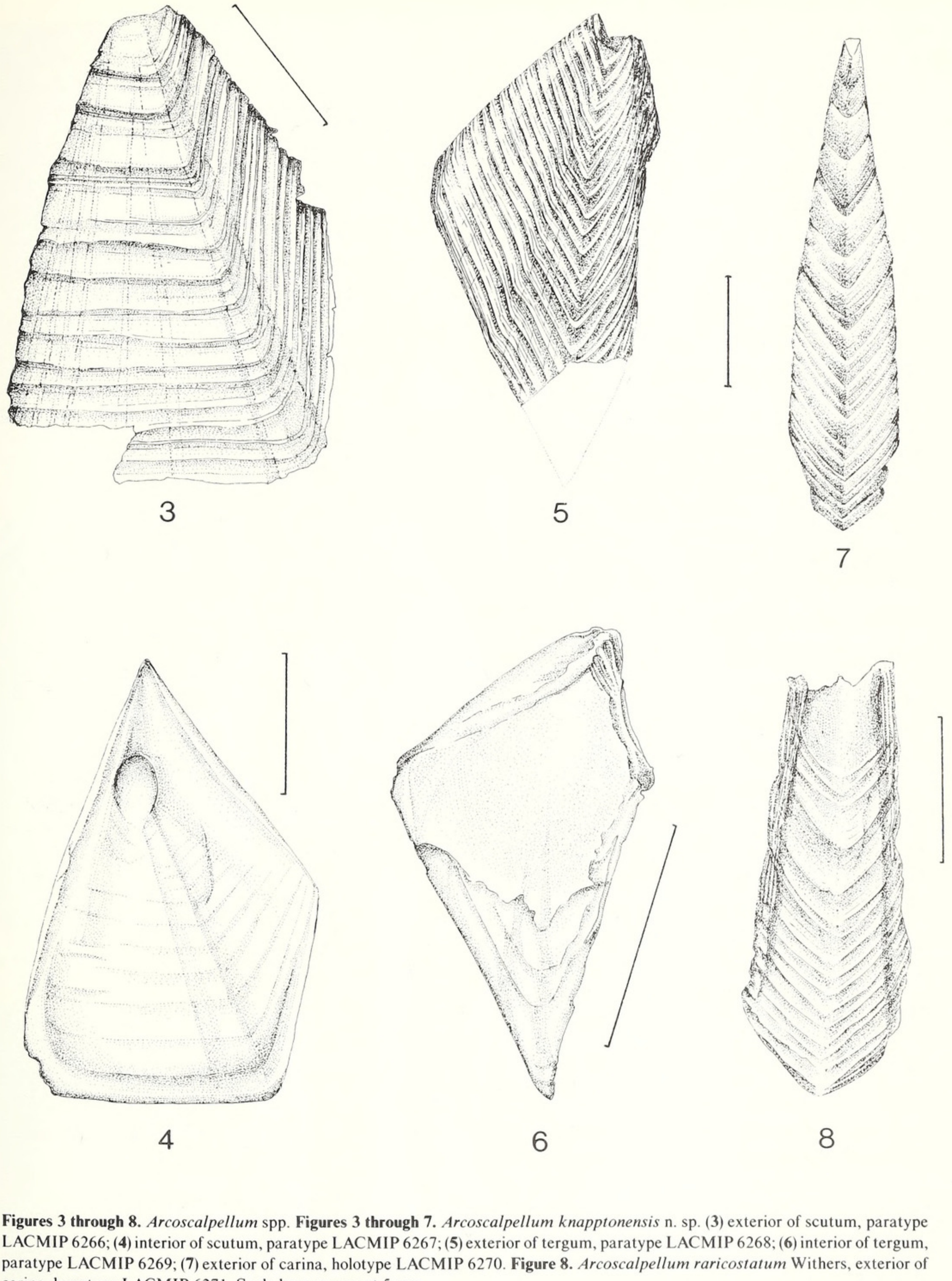
Tergum subtriangular, elongate, length about twice width, longitudinally striate; apico-basal ridge well developed, acute to flat-topped, straight to gently curved, and situated less than one-third the width of the plate from the carinal margin; a second, low, curved ridge may be present extending from the apex to the scutal margin; carinal margin weakly convex, not sharply divided into upper and lower halves; occludent margin slightly convex, short, about eight-tenths length of scutal margin; scutal margin gently sinuous.

DISCUSSION. Of the Tertiary species whose carinae are known, only the following have arched tecta:

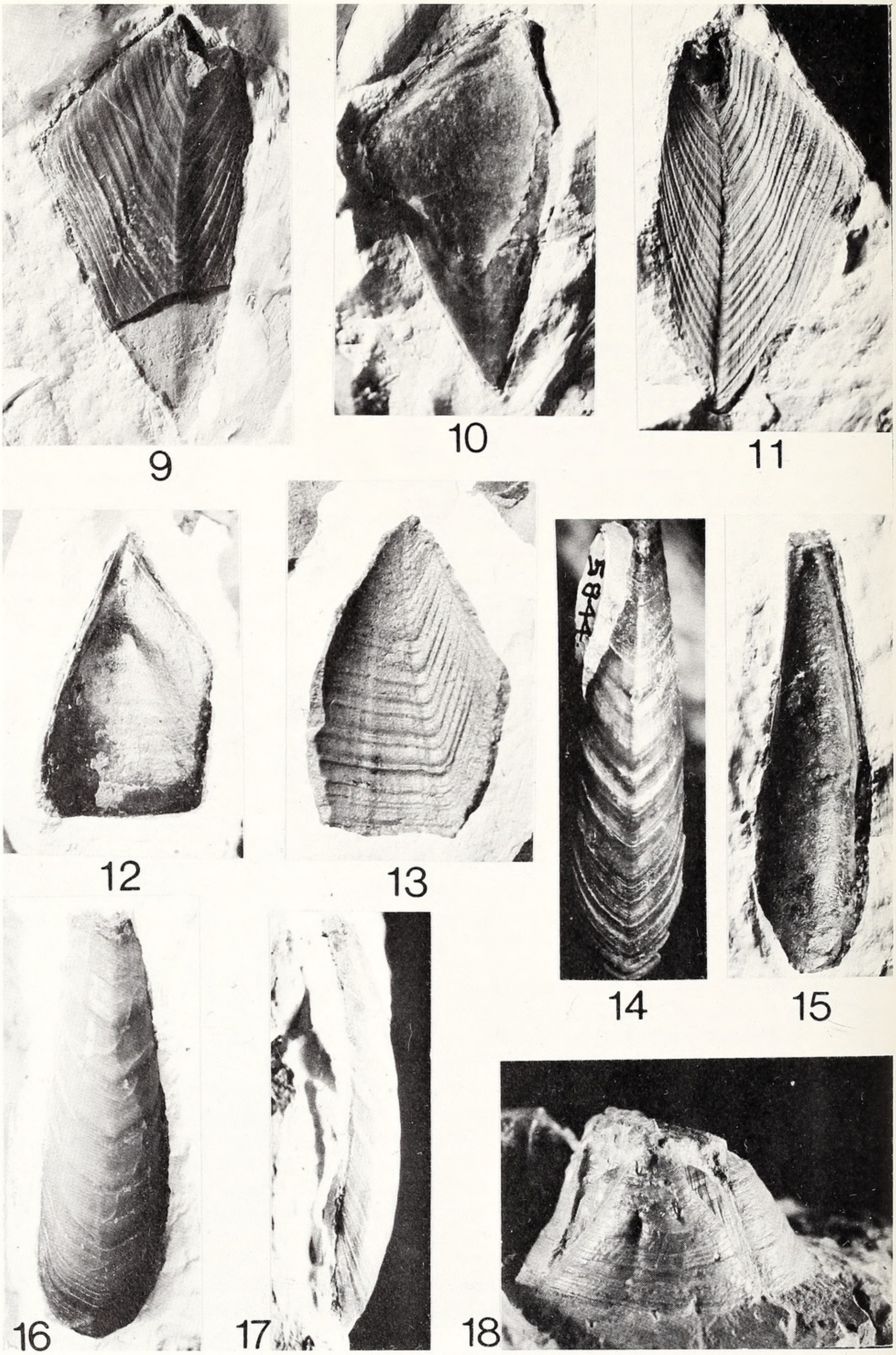
- *Arcoscalpellum euglyphum* Withers, 1924, p. 11, pl. 2, figs. 1–2); Withers (1953, p. 233, pl. 34, fig. 1); Buckeridge (1980, p. 122, fig. 34, as a member of a newly proposed genus); lower Oligocene (Whaingaroan-Duntroonian, = Latorffian-Rupelian), New Zealand.
- *A. gassinensis* (de Alessandri, 1906, p. 252, pl. 13, figs. 10–14, as *Scalpellum michelottianum* var. *gassinensis*); Withers (1953, p. 212, pl. 28, figs. 1–9); upper Eocene, Calcare di Gassino, northeast of Turin, Italy.
- *A. habanense* Withers (1953, p. 218, pl. 30, fig. 1); upper Eocene, Principe Formation, near Havana, Cuba.
- *A. hartleyi* (Withers, 1936, p. 590, pl. 11, figs. 1–5); Withers (1953, p. 232, pl. 32, figs. 1–5); (?)lower Miocene, Surma Series, Bangladesh.
- *A. sanchezi* (Withers, 1926, p. 617, pl. 26, figs, 1–7); Withers (1953, p. 215, text-fig. 84, pl. 29, figs, 1–12); upper Eocene, Principe Formation, near Havana, Cuba.

Arcoscalpellum knapptonensis is most similar to *A. gassinensis* from which it differs primarily in proportions of the plates. *Arcoscalpellum gassinensis* has a broader carina with narrower parietes set off from the tectum by conspicuous ridges, a broader scutum that in other respects is quite similar to that of *A. knapptonensis*, and a tergum that is distinguished by its shorter occludent margin and, conversely, longer scutal margin. *Arcoscalpellum habanense* is readily distinguished by the great breadth of the carina and the presence of prominent, acute, longitudinal ridges on the tectum and parietes. The carina of *A. hartleyi* is quite similar to that of *A. knapptonensis* and differs only in having a less markedly arched tectum. *Arcoscalpellum habanense* and *A. hartleyi* are known only from carinae. The carina of *A. sanchezi* is broader and more strongly bowed than that if *A. knapptonensis*, and its parietes and intraparietes flare outwards. Its scutum is narrower and has decidedly concave tergal and lateral margins. The tergum of *A. sanchezi* is similar to that of *A. knapptonensis*, except that the upper carinal margin is concave rather than straight. The carina of *A. euglyphum* has a strongly arched tectum, and the carinal parietes differ markedly from those of *A. knapptonensis* in flaring outwards and being bordered both on their inner and outer margins by prominent ridges.

Weisbord (1977) described two species of *Arcoscalpellum* from the Paleogene of Alabama for which the carinae are not



Figures 3 through 8. *Arcoscalpellum* spp. **Figures 3 through 7.** *Arcoscalpellum knapptonensis* n. sp. (**3**) exterior of scutum, paratype LACMIP 6266; (**4**) interior of scutum, paratype LACMIP 6267; (**5**) exterior of tergum, paratype LACMIP 6268; (**6**) interior of tergum, paratype LACMIP 6269; (**7**) exterior of carina, holotype LACMIP 6270. **Figure 8.** *Arcoscalpellum raricostatum* Withers, exterior of carina, hypotype LACMIP 6271. Scale bars represent 5 mm.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known. *Arcoscalpellum*(?) *choctawensis* Weisbord from the upper Eocene (Jacksonian Stage) North Twistwood Creek Member of the Yazoo Clay has thin scuta and terga; the interior of the scutum is marked by an apical furrow, and the tergum is narrow and elongate. *Arcoscalpellum toulmini* Weisbord from the Paleocene (Landenian Stage) Porters Creek Formation has a narrower tergum than *A. knapptonensis* with a distinctly shorter occludent margin, and a broader scutum with a slightly acute basitergal angle and unequal tergal and lateral margins.

ETYMOLOGY. Geographic, after Knappton, Washington.

Arcoscalpellum raricostatum Withers, 1953

Figure 8

Arcoscalpellum raricostatum Withers (1953, p. 224, pl. 36, figs. 1–2).

Arcoscalpellum aff. *raricostatum* n. sp. Withers (1953, p. 224, pl. 36, fig. 3).

LOCALITY. LACMIP locality 5844, "Lincoln Creek Formation," faunal unit 1, on Columbia River approximately 122 m east of boundary between sections 8 and 9, T 9 N, R 9 W, USGS 7.5-minute topographic quadrangle of Knappton (1973 ed.), near Knappton, Pacific County, Washington.

MATERIAL EXAMINED. Two carinae in one concretion associated with *A. knapptonensis*: one lacking apical quarter (LACMIP hypotype no. 6271); the other lacking both apical and basal parts (LACMIP hypotype no. 6335).

DESCRIPTION. The carinae are slightly bowed and have flat tecta that become gently arched towards the basal margin. The tecta are bordered by prominent ribs that bear five longitudinal ridglets. The parietes are narrow and normal to the tecta. The basal margins of the carinae are V-shaped.

DISCUSSION. Withers (1953) described *A. raricostatum* on the basis of two carinae from the Calcare di Gassino. Withers also described a basal fragment of a carina from the Principe Formation of Cuba that he considered was similar to but specifically distinct from *A. raricostatum*. The Cuban specimen differs from the types in having a slightly arched tectum with regularly spaced growth depressions and a less V-shaped basal margin. The Knappton carinae agree with the type specimens in the pronounced angulation of the basal margin and in lacking growth depressions but have the basally arched tectum characteristic of the Cuban carina. The Knappton carinae, in sharing features both with the types of *A. raricostatum* and the Cuban carina, suggest that the observed differences merely reflect individual variation within a single, widely distributed species. The morphologic variation seen in these five carinae is no greater than that to be found in the extant descendant of *A. raricostatum*, *A. michelottianum* (Seguenza, 1876) [= *A. velutinum* (Hoek, 1883)], whose geographic distribution includes the Atlantic, Indian, and western Pacific Oceans. For these reasons, I assign the Cuban and Knappton carinae to *A. raricostatum*.

The presence of these carinae amid the numerous capitular plates in the concretions ascribed to *A. knapptonensis* raises the question as to whether some of the scuta and terga may also be referable to *A. raricostatum*. Only the carina is known for this species, but as indicated by Withers (1953), *A. raricostatum* is similar to *A. michelottianum nanum* Withers, 1953, from the middle Miocene (Helvetian) of northern Italy, and to *A. michelottianum michelottianum* from the Pliocene through Recent. If the similarities seen between the carinae of these species extend to the scuta and terga, then there are no observable scuta and terga in the concretions that approach the form seen in *A. michelottianum*. Secondly, the two carinae occur in a single concretion, and the associated terga and scuta that are identifiable in this concentration do not differ from those associated with carinae of *A. knapptonensis* in other concretions.

In terms of Zevina's revision of scalpellid classification, *A. raricostatum* can be assigned to the restricted genus *Arcoscalpellum* on the basis of its close affinity to the type species of *Arcoscalpellum*, *A. michelottianum*. *Arcoscalpellum knapptonensis*, on the basis of capitular plate morphology, also appears to resemble most closely species of the restricted genus *Arcoscalpellum*.

Suborder Balanomorpha Pilsbry, 1916

Family Archaeobalanidae Newman and Ross, 1976

Subfamily Archaeobalaninae Newman and Ross, 1976

Genus *Solidobalanus* Hoek, 1913

Subgenus *Hesperibalanus* Pilsbry, 1916

Solidobalanus (*Hesperibalanus*) sp., aff. *S.* (*H.*) *sookensis* (Cornwall, 1927)

Figure 18

LOCALITY. LACMIP locality 5842, "Lincoln Creek Formation," faunal unit 4, on north bank of Columbia River about 1.6 km northeast of Knappton, Pacific County, Washington, center of N ½ of the N ½ of section 9, T 9 N, R 9 W, USGS 7.5-minute topographic quadrangle of Knappton (1973 ed.).

MATERIAL EXAMINED. Six shells in four concretions and one broken scutum; LACMIP hypotype nos. 6334, 6336.

DISCUSSION. The Knappton specimens of *Solidobalanus* agree with those of *S. sookensis* from the Sooke Formation of

Figures 9 through 18. *Arcoscalpellum* and *Solidobalanus* spp. **Figures 9 through 17.** *Arcoscalpellum knapptonensis* n. sp. **(9)** exterior of tergum, paratype LACMIP 6268, height 27 mm; **(10)** interior of tergum, paratype LACMIP 6269, height 24 mm; **(11)** external mold of tergum, paratype LACMIP 6330, height 24 mm; **(12)** interior of scutum, paratype LACMIP 6267, height 18 mm; **(13)** external mold of scutum, paratype LACMIP 6331, height 20 mm; **(14)** exterior of carina, holotype LACMIP 6270, height 30 mm; **(15)** interior of carina, paratype LACMIP 6332, height 27 mm; **(16)** exterior of carina, paratype LACMIP 6333, height 26 mm; **(17)** side view of same carina. **Figure 18.** *Solidobalanus* sp., aff. *S. sookensis* (Cornwall), rostral view of shell, hypotype LACMIP 6334, height 16 mm.

southern Vancouver Island in possessing a recurved carina, a large rhomboidal orifice, broad radii with oblique summits, and an irregularly plicate shell. Opercular plates are difficult to extract from the indurated matrix, and only the interior of a single, broken scutum could be examined in any detail. This scutum differs from those described for *S. sookensis* in lacking a depressor muscle pit and in appearing to have a straight rather than recurved ridge bordering the adductor muscle pit.

Solidobalanus sookensis and the Knappton species differ markedly from the upper Eocene Cowlitz Formation species *S. cornwalli* in having broad, transparietal radii with crenulate sutural edges, rather than narrow, non-transparietal radii with smooth sutural edges, and in possessing an unusually high and thickened ridge bordering the scutal adductor muscle pit. The Pliocene species *S. proinus* and the Pleistocene and extant species *S. hesperius* can be distinguished by their possession of a true scutal adductor ridge and of callosities and rugosities on the interior of the scutum.

BARNACLES AS BIOSTRATIGRAPHIC INDICATORS

Little consideration has been given to the potential of cirripeds as biostratigraphic indicators, particularly in North America. Cheetham (1963) and Weisbord (1977) recognized the value of barnacles in biostratigraphy, but only two authors have attempted to develop biostratigraphic zonations based on barnacle assemblages. Mellen (1973), utilizing Collins' (1973) study of the lepadomorphs from the Upper Cretaceous of Alabama and Mississippi, was able to recognize three zones in the "Selma Chalk." Zullo (1979b, 1980) was able to distinguish four assemblage zones in the middle Eocene through lower Miocene formations of North Carolina. Two of these zones, the upper middle Eocene *Arcoscalpellum subquadratum* zone and the lower upper Eocene *A. jacksonense* zone, can be recognized throughout the southeastern Atlantic and eastern Gulf Coastal Plains.

The Knappton arcoscalpellids demonstrate that certain barnacles are useful in interregional and, in this case, intercontinental correlation. If it appears improbable that sessile organisms are capable of attaining rapid and widespread distribution, it is only necessary to compare the modern distribution of a related species. *Arcoscalpellum michelottianum* is found in the North and South Atlantic basins, the Indian Ocean, and the western Pacific between 40 and 2900 m. This species was originally described from the Astian and Plaisancian of Sicily and is considered to have evolved from *A. raricostatum* through the Italian Miocene taxon *A. michelottianum nanum*. The absence of *A. michelottianum* in the eastern Pacific may be an artifact of sampling but is probably related to the closing of Central American seaways during the time that this species was attaining its present distribution. Thus, it appears that *A. michelottianum* achieved virtual worldwide distribution in a three-million-year period through dispersal of planktonic larval stages. Examples of wide-ranging species are not limited to the Lepadomorpha ("goose barnacles"), for several balanomorph species ("acorn barnacles"), including *Balanus trigonus* Darwin, 1854, *B. calidus* Pilsbry, 1916, and *B. venustus* Darwin, 1854, have developed tropicopolitan or Tethyan distributions by natural means.

Reconnaissance of Tertiary and particularly Paleogene marine units of the Atlantic and Gulf Coastal Plains and the Pacific Coast indicates that an array of lepadomorph and balanomorph remains has been overlooked. Systematic collection and analysis of these cirriped assemblages may provide a valuable tool in stratigraphic interpretations.

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