

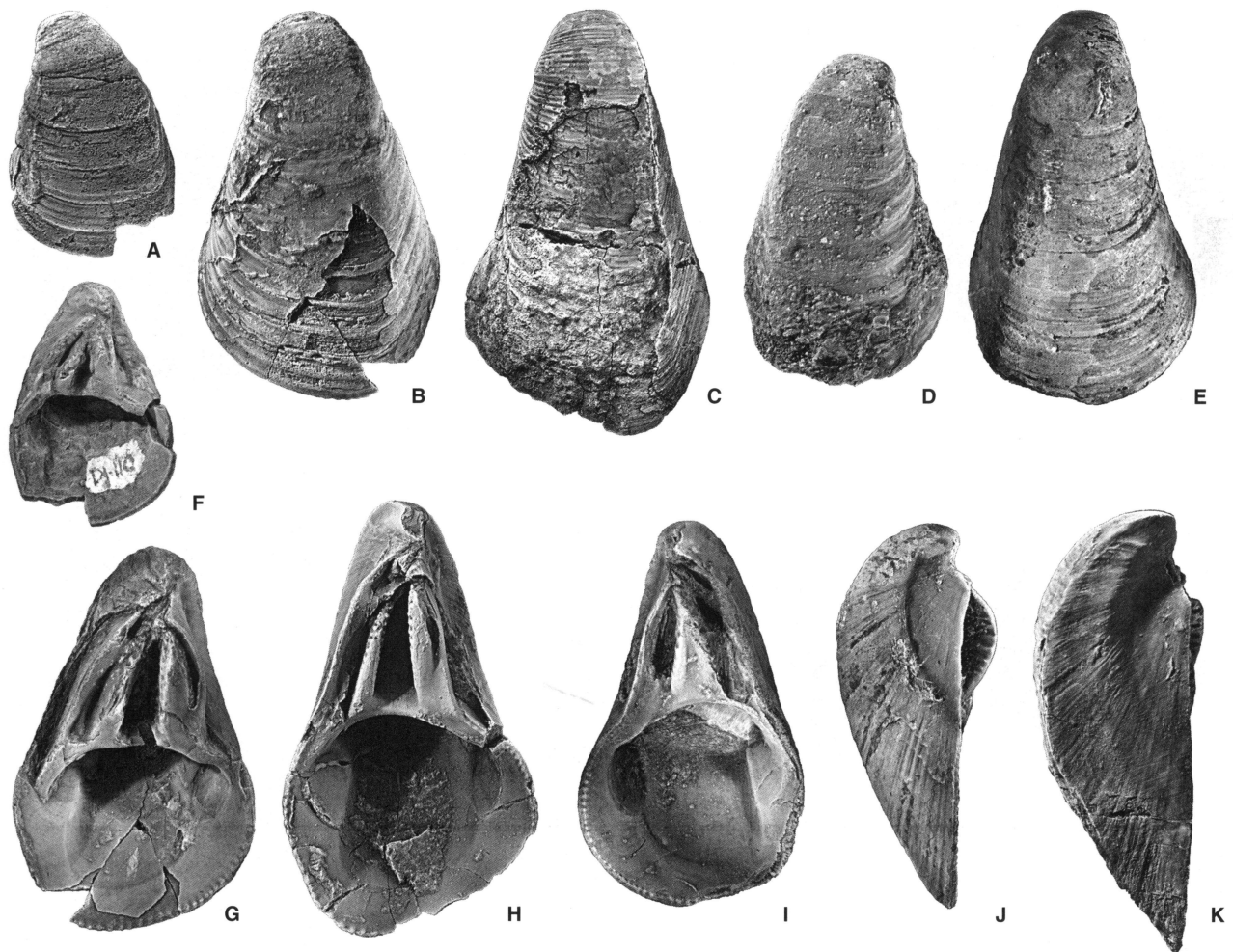
*Holotype.* LACMIP 13531 (Text-fig. 8G, K-M), LACMIP loc. 10084.

*Paratypes.* LACMIP 9917 [= specimen of *Opis* sp. B figured by Popenoe (1973, pl. 2, fig. 25)], 13525-13530 and 13532.-13533

*Material examined.* One hundred and ten specimens (43 left valves, 56 right valves and 11 double valves): one? from Granite Bay (Area 9); 109 from Santa Ana Mountains (Area 15).

*Diagnosis.* Moderately large-sized, moderately narrow and moderately elongate *Hesperopis*. Umbones anteriorly directed. Posterior umbonal ridge weak. Corcelet moderately weak. Commarginal ribs moderately strong but finer and more closely spaced on larger specimens. Cardinal 3b narrow and moderately long.

*Description.* Shell of moderately large size (up to 68 mm in height and 48 mm in length, same specimen); moderately thick-walled. Equivalved, inequilateral (higher than long), inflated and trigonal. Corcelet side of shell posteriorly truncate; lunule side posteriorly rounded. Beaks high and prosogyrous. Umbones narrow and directed anteriorly. Posterior umbonal angulation weak. Corcelet furrow and corcelet ridge moderately weak. Lunule deep set, large, wide and heart-shaped; lunular area bulges towards the valve margin creating a pouch-like socket for 2b. Escutcheon area with weak radial furrow, bordered posteriorly by weak to moderately weak radial ridge. Commarginal ribs moderately strong, close set and of uniform strength on juveniles (up to height 21 mm); commarginal ribs becoming much weaker, more closely spaced, and less uniform on larger specimens. Hinges high. Left-valve hinge with two nearly equally strong cardinals: 2 long but slightly shorter than 4b; 4b serrate on both sides; and 3b socket long. Right-valve



**TEXT-FIG. 9.** *Opes* (*Hesperopis*) *vancouverensis* Whiteaves, 1879. All specimens from Locality 1 (south-west Denman Island, British Columbia). All  $\times 1$ . Specimens coated with ammonium chloride. A, F, hypotype, RBCM.EH2008.016.0002, left valve. A, exterior. F, interior. B, G, hypotype, RBCM.EH2008.016.0003, left valve. B, exterior. G, interior. C, H, K, hypotype, RBCM.EH2008.017.0001, left valve. C, exterior. H, interior. K, escutcheon/corcellet view. D, hypotype, RBCM.EH2008.016.0004, left valve. E, I-J, hypotype, RBCM.EH2008.016.0005, right valve. E, exterior. I, interior. J, lunule view.

hinge with two cardinals: 3b strongly trigonal, narrow, moderately long and serrate on both sides; 5b low and thin. Lunular margin deeply depressed. Internal-ligament pit sunken, narrow and situated dorsally of 5b and encroaching on its posterior end.

*Remarks.* Popenoe (1942, pp. 178–179, fig. 4) listed *Opis* sp. cf. *O. triangulata* (Cooper) in his checklist of Upper Cretaceous strata in the Santa Ana Mountains, southern California (Area 15). The specimens he used are stored in the LACMIP collection. Inspection of this material revealed that the specimens from all of his listed localities, except for CIT loc. 302 (= LACMIP loc. 10098) (see 'Remarks' on *O. (H.) popenoei*), are *O. (H.) anae* from the upper Holz Shale Member. One of these specimens of this species is designated herein as paratype, LACMIP 9917, and it is the same specimen (hypotype, UCLA 59072) figured by Popenoe (1973, p. 20, pl. 2, fig. 25) and identified by him as *Opis* sp. B from the Holz Shale Member. Saul (1982, p. 73, fig. 3) listed *Opis* aff. *O. triangulata* (Cooper) from the Holz Shale Member in Area 15. The material she used is stored in the LACMIP collection, and inspection of this material revealed that these specimens are *O. (H.) anae*.

*Opis (H.) anae* is similar to *O. (H.) vancouverensis* but differs from the latter by having a larger size, broader shape (especially posteriorly), less tendency to have obsolete commarginal ribbing, stronger corcelet ridge and slightly wider teeth. *Opis (H.) anae* is also similar to *O. (H.) triangulata* but differs from the latter by having smaller size, less tendency for anteriorly narrowing beaks, stronger commarginal ribbing, shorter teeth and absence of any strong growth checks.

An internal mould of what is probably *O. (H.) anae* from LACMIP loc. 17871 is the only known specimen of an opine from the Chico Formation in northern California.

*Stratigraphical range.* Upper Lower Campanian.

*Distribution.* Tentatively from Chico Formation at Granite Bay, east of Sacramento, Placer County, California (Area 9); Ladd Formation, uppermost Holz Shale Member, Santa Ana Mountains, Orange County, California (Area 15).

*Opis (Hesperopis) vancouverensis* Whiteaves, 1879

Text-figures 3A, 9

1879 *Opis vancouverensis* Whiteaves, 1879, p. 158, pl. 18, figs 4–4a.

1997 *Opis vancouverensis* Whiteaves; Ludvigsen and Beard, p. 101, fig. 55 (three views of a left valve, the two interior views of which are reverse images).

*Holotype.* CGS 5691 from west side of Denman Island (coll. Richardson in 1871), Strait of Georgia, British Columbia.

*Hypotypes.* RBCM.EH2008.016.0001 to RBCM.EH2008.016.0005, and RBCM.EH2008.017.0001 [= VIPM 151 figured by Ludvigsen and Beard (1997, fig. 55)].

*Material examined.* Twelve specimens (six left valves, four right valves and two double valves): nine from Denman Island (Area 2); three from Santa Monica Mountains (Area 14).

*Diagnosis.* Medium-sized, narrowly trigonal and elongate *Hesperopis*. Beaks very high. Umbones anteriorly directed. Posterior umbonal ridge weak. Corcelet weak; strongest near beaks, otherwise flattish. Commarginal ribs very weak to moderately strong. Inner valve margins crenulate. Cardinal 3b very narrow and very long.

*Description.* Shell of medium size (up to 56 mm in height and 32 mm in length, same specimen); thick-walled. Equivalved, inequilateral, inflated and elongate trigonal. Corcelet side of shell posteriorly truncate; lunule side posteriorly rounded. Beaks very high, prosogyrous and incurved. Umbones narrow and directed anteriorly. Posterior umbonal carina moderately rounded. Corcelet furrow and corcelet ridge weak. Lunule deep set. Escutcheon weakly delimited by narrow raised area; escutcheon flattish but raised slightly near commissure. Commarginal ribs very weak to moderately strong, uniformly spaced on umbones; ribs becoming narrower and less uniformly spaced ventrally. Hinge very high. Left-valve hinge with two cardinals: 2 narrow, elongate, serrate on both sides, shorter and closer to beak than 4b, and bordered by longer deep socket for 3b; 4b serrate on both sides. Right-valve hinge with two cardinals: 3b moderately large, trigonal, very narrow, very long and serrate on both sides; 5b on anterior side appressed to valve margin. Ligament narrow beneath beaks; internal-ligament pit sunken, narrow, elongate, widening slightly ventrally and impinging on dorsal ends of 5a and 4b. Inner valve margins crenulate.

*Remarks.* *Opis (H.) vancouverensis* resembles *O. (H.) triangulata* in the elongation of the beaks, but *O. (H.) vancouverensis* differs by having a smaller shell size and weaker sculpture.

Three rather poor specimens of *O. (H.) vancouverensis* Whiteaves, 1879 have been recovered from the Tuna Canyon Formation in the Santa Monica Mountains (Area 14). Two of them are from LACMIP loc. 4818 in lower Santa Ynez Canyon. This locality yielded the ammonite *Metaplacenticerias pacificum* (Smith, 1900), but, unfortunately, collectors wandered about and collected from above and below the strata that yielded *M. pacificum*. According to J. Alderson (pers. comm. 2008), the *Opis* specimens are probably from underlying silty sandstone and, therefore, would be slightly older than the beds containing *M. pacificum*. This ammonite ranges from late

middle to early late Campanian age (Elder and Saul 1996), thus the *Opis* at locality 4818 is approximately middle Campanian in age. The third opine specimen from the Tuna Canyon Formation is tentatively identified as *O. (H.) vancouverensis*, because it is a poorly preserved left valve that shows of sculpture similar to that found in *O. (H.) vancouverensis*. This specimen is from LACMIP loc. 20215 in Rivas Canyon near Pacific Palisades, and the associated fossils also occur at a nearby locality that yielded abundant *M. pacificum*.

Anderson (1958, p. 123) reported '*Opisoma*' *vancouverensis* (Whiteaves) from the south-west side of Denman Island, which is just east of the coast of Vancouver Island, British Columbia. Ludvigsen and Beard (1997) reported *Opis vancouverensis* from the 'Trent River' Formation on the west side of Denman Island, but these outcrops were mapped as the Cedar District Formation by Katnick and Mustard (2001). According to Ludvigsen and Beard (1997), this opine is one of the rarest bivalves in Cretaceous rocks of Vancouver Island and vicinity.

*Stratigraphical range.* Middle–upper Middle Campanian.

*Distribution.* Cedar District Formation, upper part, west side Denman Island, British Columbia (Area 2); upper Tuna Canyon Formation, lower Santa Ynez Canyon and Rivas Canyon, Santa Monica Mountains, Los Angeles County, California (Area 14).

*Opis (Hesperopis) triangulata* (Cooper, 1894)

Plates 1–2, Text-figure 10

- 1894 *Corbula triangulata* Cooper, p. 49, 61, pl. 2, fig. 42 [not pl. 4 as stated].  
 1896 *Opis triangulata* (Cooper); Cooper, pp. 332–333, pl. 47, figs 7–9.  
 1958 *Opisoma pacifica* Anderson, pp. 122–123, pl. 26, figs 5–6.  
 1978 *Opis* cf. *O. triangulata* Dawson, pl. 1, fig. 18.

*Primary types.* Of *Corbula triangulata* Cooper, 1894, lectotype CASG 624 (ex CSMB 13752), designated by Stanton (1895), Point Loma Formation at Point Loma, San Diego County, California (Area 17). Of *Opisoma pacifica* Anderson, 1958, holotype CASG 29118.03, CASG loc. 29118, Moreno Formation, Merced County, California (Area 11).

*Hypotypes.* LACMIP 13537–13544; SDSNH 33989–33990, 67147–67148; and CASG 29120.02.

*Material examined.* Forty-seven specimens (14 left valves, 23 right valves and 8 double valves): one from Gualala (Area 8); 28 from Garzas to Los Banos Creek (Area 11); two from north-east of Cape San Martin (Area 12); two from Pebblestone Shut-In (Area 13); five from Carlsbad (Area 16); three from Pt. Loma

(Area 17); two from La Mision (Area 18); and four from Punta China (Area 19).

*Diagnosis.* Large-sized, narrowly trigonal and elongate *Hesperopis*. Beaks very high. Umbones directly anteriorly. Posterior umbonal carina weak to moderately strong. Corcelet weak to moderately weak. Shell smoothish to weakly sculptured with commarginal ribs. Growth checks can be very strong. Cardinal 3b very narrow and very long. Internal-ligament pit moderately broad.

*Description.* Shell of large size (up to 88 mm in height and 48 mm in length, same specimen); moderately thin-walled to thick-walled. Equivalved, inequilateral, inflated, narrowly trigonal and elongate. Corcelet side of shell posteriorly truncate; lunule side posteriorly rounded. Beaks very high, prosogyrous and incurved. Umbones narrow. Posterior umbonal carina broadly rounded to moderately prominent. Corcelet furrow weak, corcelet ridge moderately weak. Lunule deep set, very wide, smoothish and gently convex. Escutcheon weakly delimited by narrow raised area; escutcheon long, smoothish and gently convex. Commarginal ribs on juveniles moderately strong, closely and uniformly spaced; adult shell smoothish (showing only growth lines) or with irregularly spaced growth checks, becoming especially strong ventrally on some specimens. Left-valve hinge with two cardinals: 2 closer to beak than 4b, and 2 bordered by long deep socket for 3b; 4b elongate, thin and serrate on both sides. Right-valve hinge with two cardinals: 3b trigonal, strong, very narrow, very long and serrate on both sides; 5b low and thin. Internal-ligament pit sunken, moderately broad and situated dorsal to 4b.

*Remarks.* *Opis (H.) triangulata* is most similar to *O. (H.) vancouverensis*, but *Opis (H.) triangulata* differs by having a much larger shell size and stronger sculpture. Cooper (1894) described *Opis (H.) triangulata* based on two specimens collected by Fairbanks (1893), who reported that the fossiliferous sandstone, from which these specimens were taken, crops out at the base of the cliffs on the outer (western) side of Point Loma and also occurs as re-deposited boulders in the overlying conglomerate. Cooper (1894) did not designate a type specimen, but Stanton (1895), who requested Cooper's Point Loma material from the CSMB, observed material that consisted of Cooper's figured specimen and a second, much larger but broken specimen. Stanton (1895, p. 59) recognized both specimens as belonging to the genus *Opis*, and he indicated that the specimen figured by Cooper (1894, pl. 2, fig. 42) was the 'type.' Stanton, thus, designated the lectotype although Anderson (1958) referred to this specimen as the holotype. In 1896, Cooper wrote that when describing the species, he had not seen the larger specimen mentioned by Stanton in 1895, and had referred his species to *Corbula* because of a

smaller broken specimen that revealed a single, large median tooth. Both this small broken specimen (a syntype because Cooper indicated its use in describing the hinge) and the larger, later figured specimen (Cooper, 1896, pl. 47, fig. 7) appear to be lost. Coan (1981) indicated that CSMB 13752 was a syntype. Even though Coan (1981, p. 155) used Cooper's original generic assignment for the species, Coan was aware that Stanton had placed Cooper's species in the genus *Opis*. Unfortunately, the lectotype is a juvenile (Text-fig. 10C-D), but well-preserved conspecific specimens from the Point Loma Formation near Carlsbad (Area 16) have been used to help describe the adult characteristics of this species. Anderson (1958, p. 122) restated some of Cooper's (1894) comments and some of Stanton's (1895) comments regarding *Opis triangulata* but did not figure any specimens.

Fifty-three per cent of the examined specimens of this species are double valves, which is the highest percentage for the studied species of *Hesperopis*. All of the double valves are from the San Diego area. No growth checks (i.e. environmentally caused) were found on any of the specimens from the San Diego area.

Sundberg (1979, table 1) reported *Opis* cf. *O. triangulata* (Cooper) from the Cabrillo Formation on the east side of Point Loma, San Diego County, southern California (Area 17). Inspection of his collection, which is stored at California State University Fullerton, revealed that the specimens are *O. (H.) triangulata*. A few specimens of *O. (H.) triangulata* (Cooper, 1894) were recovered by Dawson (1978) from the same area where Sundberg collected his fossils.

All the specimens of *O. (H.) triangulata* from the west side of the San Joaquin Valley (Area 11) are single valves. Most are covered with growth checks although some have them only on the adult part. Some specimens from a single locality have them, whereas other specimens from the same locality do not. All the studied specimens from LACMIP loc. 22661, however, have strong growth checks. At both LACMIP locs 10685 and 26342, some of the specimens have growth checks, whereas and others do not.

*Opis (H.) triangulata* was detected at two localities in the El Piojo Formation in the Lake Nacimiento area, San

Luis Obispo County, California (Areas 12-13). The locality with the better preserved fossils (LACMIP loc. 12245) is a reworked fossiliferous boulder from a conglomerate that crops out just west of Pebblestone Shut-In, western Lake Nacimiento, San Luis Obispo County (Area 13). The age of this boulder that contains *Opis triangulata* is probably early Maastrichtian, based on the presence of the bivalve *Calva (Penecallista) marina* Saul and Popenoe, 1992, whose geological age range is latest Campanian? and early Maastrichtian.

The other Nacimiento River drainage locality (UCMP loc. A-3435) is on Negro Fork of the Nacimiento River, approximately 32 km north-west of the other locality and 14 km north-east of Cape San Martin, Monterey County (Area 12). Preservation is very poor and species identifications of the fossils at this locality are tentative. Saul (1986, p. 26) mentioned that the rudist *Coralliochama* cf. *C. orcutti* White, 1885 occurs at the locality. Locality UCMP A-3435 is most likely the locality from which Taliaferro (1944) *Opus [sic] triangulata* was collected. Saul (1986, p. 26) erred in suggesting that might it have come from a boulder in a conglomerate that crops out just west of Pebblestone Shut-In.

Weaver (1944) included *Opis triangulata* in a faunal list of fossils from the Gualala Formation near Gualala, Mendocino County, California (Area 8). Anderson (1958, p. 69) noted Weaver's list and followed it by another list of Gualala species, including *Opis (Opisoma)* aff. *O. vancouverensis*, based on specimens, which were collected by S. G. Clark. During this present investigation, Clark's specimens could not be found at either UCMP or CASG. Elder *et al.* (1998) reported *Opis rosarioensis* from the Anchor Bay Member of the Gualala Formation, and this material is also missing. During this present investigation, a specimen of an opine from this formation was studied. It is poorly preserved, but its narrowness resembles *O. (H.) triangulata*. It is tentatively concluded here that all the Gualala Formation reports of opines are *O. (H.) triangulata*.

There are potential opine specimens at UCMP from five Cretaceous localities in the Covelo district, western part of Round Valley, Mendocino County, California (Area 7). A bivalve? impression is labelled *Opis?*, but the impression is too indefinite for even identification to a family. If *O. triangulata* were correctly identified from this area, they

#### EXPLANATION OF PLATE 1

Figs 1-9. *Opis (Hesperopis) triangulata* (Cooper, 1894). All  $\times 1$ . All left valves. Specimens coated with ammonium chloride. 1, LACMIP hypotype 13537, LACMIP loc. 10685, exterior. 2, LACMIP hypotype 13538, LACMIP loc. 10685, exterior. 3, LACMIP hypotype 13539, LACMIP loc. 10685, exterior. 4, SDSNH hypotype 67148, SDSNH loc. 3403, exterior. 5, LACMIP hypotype 13540, LACMIP loc. 26342, exterior. 6, 9, SDSNH hypotype 67147, SDSNH loc. 3869. 6, exterior. 9, interior. 7, SDSNH hypotype 33989, SDSNH loc. 3384, exterior. 8, LACMIP hypotype 13541, LACMIP loc. 22611, interior.