

mon especially toward venter, 6 to 13 (usually 8) radial ribs (including bifurcated ones), ribs in some cases scaly; hinge short, right valve with two long teeth on each side of a narrow resilifer, inner margin of right valve with numerous pits; left valve with two long sockets on each side of a moderately wide resilifer, inner margin of left valve with numerous tubercles; muscle scar monomyarian, elliptical, and posterior of center of each valve.

Type specimens.—Lectotype of *Plicatula variata* ANSP 4432, here designated; lectoparatypes ANSP 4432a, 4432b. Holotype of *P. onoensis* CASG 66509.01; paratype CASG 66510.01; hypotype [=voucher] CASG 66511.01.

Type localities.—Of *P. variata*: North Fork Cottonwood Creek, Shasta County, California (Ogo Member of the Budden Canyon Formation, Early Cretaceous). Of *P. onoensis*: holotype from CASG loc. 66509; paratype from CASG loc. 66510; Anderson's (1938) hypotype CASG loc. 66511 [=CASG loc. 113, see "Discussion"]; all from North Fork Cottonwood Creek, Shasta County, California (Ogo Member of the Budden Canyon Formation, Early Cretaceous).

Dimensions.—ANSP 4432, right valve, height 16.7 mm, length 15.1 mm, thickness 7.7 mm. ANSP 4432a, left valve, height 14.5 mm, length 12.9 mm, thickness 2.7 mm. ANSP 4432b, articulated specimen, height 12.5 mm, length 11.2 mm, thickness of double valves 5.4 mm. CASG, 66509.01, articulated specimen, height 16.9 mm, length 16.2 mm, thickness of double valves 7.8 mm. CASG 66510.01, articulated specimen, height 15.2 mm, length 13.8 mm, thickness of double valves 7.2 mm. CASG 66511.01, articulated specimen, height 16.4 mm, length 14.1 mm, thickness of double valves 8.9 mm.

Discussion.—Gabb did not publish type specimen designations in 1864 or 1869 and only infrequently noted them on labels. Stewart (1927, 1930) commonly indicated that the specimen figured by Gabb was the holotype, but where Gabb said he had several specimens, these should be considered syntypes, and Stewart's "holotype" a lectotype. Obviously, for those species of which Gabb indicated he had only a single specimen, that specimen would be the holotype, as would those specimens for which he wrote "type" on the label. In the absence of the specimen of *P. variata* figured by Gabb, Stewart (1930) illustrated specimens from a box labeled, in Gabb's hand, "(dupl. type), Shasta Group, Cottonwood Creek." Stewart (1930) suggested that if the original material from Battle Creek, Shasta County, could not be found, a neotype should be designated from specimens collected from that locality, but "Battle Creek, Shasta County," is an unsatisfactory type locality because it is ill-defined and unlikely to produce specimens.

Gabb (1864; 1869) listed only two species from Battle Creek: *Plicatula variata* Gabb, 1864 and *Ammonites subtricarinated* Gabb, 1864 [= *A. tehamaensis* Gabb, 1869 = *Peroniceras tehamaensis* (Gabb, 1869) = *P. rousseauxi* Grossouvre, 1894]

(Matsumoto, 1960). *Peroniceras tehamaensis* is the basis of the Coniacian age for Battle Creek beds, Tehama County (Matsumoto, 1960). There is, however, no indication in Gabb, 1864 or 1869, that the two species came from the same locality. The ammonite was "presented to the Geological Survey of California by a gentleman at Battle Creek, Tehama County and said to have come from the vicinity" (Gabb, 1864, p. 61), but Gabb recorded the bivalve as from Battle Creek, Shasta County in 1864 and from the Shasta Group in 1869. In Bear Creek to the north of the North Fork of Battle Creek, Shasta County, the lower beds of the Redding Formation yield a Coniacian age fauna, and in canyons to the south of the South Fork of Battle Creek, Tehama County, the oldest beds of the Chico Formation have yielded a late Coniacian age fauna. No outcrops of the "Shasta Series" (=Lower Cretaceous) are known from the east side of the Great Valley. Lydon and O'Brien (1974, pl. 1) showed no outcrops of the "Chico" Formation along the North Fork of Battle Creek, Shasta County, although considering the scale of the map and its reconnaissance nature, small outcrops of the Redding Formation might none-the-less be present. Helley et al. (1981) also showed no outcrops of Cretaceous strata along Battle Creek or its forks in Shasta and Tehama Counties, California.

Although Gabb (1864; 1869) did not list *P. variata* from the "Shasta Series" on North Fork Cottonwood Creek, Shasta County, he had, in addition to the box at the Academy of Natural Sciences of Philadelphia, specimens from North Fork Cottonwood Creek that are at the University of California Museum of Paleontology. Gabb's abundance of specimens of *P. variata* from the "Shasta Series" on North Fork Cottonwood Creek suggests that the Battle Creek location is an error.

Designating ANSP 4432 (from North Fork Cottonwood Creek) as the lectotype provides *P. variata* with a specimen considered by Gabb to belong to this species and to be a type specimen. Additionally, the *Hertleinites aguila* zone on North Fork Cottonwood Creek, Shasta County, has produced well-preserved specimens of *Plicatula* that have been identified as *P. variata* over the past century.

Plicatula onoensis Anderson (1938) was described from its type locality and a few other localities, all in the vicinity of Ono, California. Strata in the vicinity of the type locality have been studied by Murphy (1956) and Murphy et al. (1964, 1969) and are considered to be in the upper part of the Ogo Member of the Budden Canyon Formation, from the *Hertleinites aguila* zone, and thus of late Hauterivian age.

Imlay (1960) discussed hypotype locality CASG loc. 113 and suggested that Anderson had included, under this number, collections along Mitchell Creek from 137 to 183 m (450 to 600 ft) below the base of the Roaring River Member in the Ogo Member of the Budden Canyon Formation. Murphy (*in* Imlay,

FIGURE 3—Cretaceous *Plicatula* from the Pacific coast of North America. Unless otherwise noted, specimens coated with ammonium chloride. 1–8, *Plicatula variata* Gabb, 1864; 1, lectotype ANSP 4432, Cottonwood Creek, California, right valve (uncoated), height 16.7 mm, $\times 2.7$; 2, hypotype CASG 67779.01, CASG loc. 62591, right valve, height 16.8 mm, $\times 2.7$; 3, hypotype LACMIP 8052, LACMIP loc. 22970, right valve, height 26.7 mm, $\times 1.8$; 4, hypotype LACMIP 8053, LACMIP loc. 22896, right-valve interior, height 15.7 mm, $\times 2.9$; 5, lectoparatype ANSP 4432A, Cottonwood Creek, California, left valve (uncoated), height 14.5 mm, $\times 3.1$; 6, hypotype LACMIP 8054, LACMIP loc. 22896, left valve, height 17 mm, $\times 2.7$; 7, hypotype LACMIP 8055, LACMIP loc. 22897, left-valve interior, height 14.1 mm, $\times 3$; 8, hypotype LACMIP 8052, LACMIP loc. 22970, anterior view, thickness of both valves 11.8 mm, $\times 1.7$; 9–11, *Plicatula allisoni* new species; 9, paratype UCMP 39884, UCMP loc. A-6284, right valve, height 17.4 mm, $\times 2.6$; 10–11, holotype UCMP 39883, UCMP loc. B-5688; 10, left valve, height 33.2 mm, $\times 1.3$; 11, anterior view, thickness of both valves 15 mm, $\times 1.2$. 12–18, *Plicatula modjeskaensis* new species, LACMIP loc. 10888; 12, holotype LACMIP 8056, right valve, height 12.8 mm, $\times 3.5$; 13, paratype LACMIP 8057, right valve, height 13.6 mm, $\times 3.3$; 14, paratype LACMIP 8058, right-valve interior, height 8 mm, $\times 4.6$; 15, paratype LACMIP 8059, left valve, height 15 mm, $\times 3$; 16, holotype LACMIP 8056, left valve, height 12.8 mm, $\times 3.5$; 17, paratype LACMIP 8060, left valve, height 11.3 mm, $\times 3.6$; 18, holotype LACMIP 8056, anterior view, thickness of both valves 3.7 mm, $\times 3.5$; 19, *Plicatula* cf. *P. modjeskaensis* new species, hypotype LACMIP 8061, LACMIP loc. 10883, right-valve interior, height 14.2 mm, $\times 3$.

1960) stated that there are two fossil zones at the head of Mitchell Creek west of the road, and Imlay (1960) considered the lower of these to be the Hamlin-Broad zone and of early late Hauterivian age. Murphy et al. (1969), however, rejected Hamlin-Broad as a zone because the fossils of CASG loc. 113 were collected in a general area at the head of Mitchell Creek, and at least four horizons are represented by the fossils, most of which were donated to the California Academy of Sciences by two amateur collectors; namely, Mr. Hamlin and E. J. Broad. Possibly the *P. onoensis* reported by Anderson from 137 to 183 m (450 to 600 ft) below the Roaring River Member are of early late Hauterivian age.

Other mollusks recorded by Murphy (1956, fig. 6) as occurring with *P. onoensis* are suggestive of a moderate-depth habitat. One of the most common ammonites, *Lytoceras auleum*, reflects quiet, deeper marine waters (Dailey, 1973). Perhaps, there was either downslope transport of shallow species, or there was flotation of the ammonites. Specimens of *Plicatula* from strata crossing the North Fork Cottonwood Creek are commonly in aggregations, suggesting a reflection of communal living, although to what substrate the *Plicatula* were attached is not clear.

Plicatula variata resembles *Plicatula torreonensis* Imlay (1940, p. 144, pl. 2, figs. 41, 42) from Lower Cretaceous (Berriasian-Valangianian) strata of eastern Durango, Mexico, but *P. variata* differs by having fewer radial ribs on both valves, much rarer radial riblets in the interspaces, and non-spinate radial riblets in the interspaces.

Among Early Cretaceous (Neocomian) *Plicatula* of France figured by Orbigny (1843), *Plicatula radiola* Lamarck, 1819, is most similar to *P. variata* in having prominent and widely spaced radial ribbing, as well as a flat to concave upper (left) valve. *Plicatula variata* differs in having bifurcated ribs or scaly ribs but no spinose ribs.

Plicatula variata differs from *P. modjeskaensis* new species in having a more convex right valve and ribs that are not spinose. The number of ribs varies in both species, and a considerable overlap in rib count exists. Specimens with the fewest ribs are *P. variata*, and those with the greatest number of ribs are *P. modjeskaensis*. Those specimens falling in the overlap in rib count are assigned to species based on other characters.

Plicatula variata differs from *P. allisoni* new species by having smooth interspaces between the primary radial ribs and by having much weaker nodes on the primary ribs.

Material examined.—Lectotype, and two lectoparatypes of *P. variata*. Holotype, paratype, and hypotype [=voucher] of *P. ononensis*. Approximately 100 specimens of *P. variata* from the North Fork Cottonwood Creek area, northern California (LACMIP locs. 22788, 22896, 22897, 22914, 22970, and CASG locs. 62591 and 67779). About one-third of these 100 specimens are articulated.

Distribution.—Ogo Member of the Budden Canyon Formation, Ono area, west of Redding, Shasta County, northern California.

Age.—Early Cretaceous (late Hauterivian).

PLICATULA ALLISONI new species

Figure 3.9–3.11

Plicatula radiola Lamarck. Allison, 1974:table 5. Not *Plicatula radiola* Lamarck, 1819.

Diagnosis.—A large *Plicatula* with a convex right valve and a concave left valve; primary radial ribs (13–16) on both valves narrow, noded to spinose and interspaces (especially on right valve) with finely beaded radial sculpture.

Description.—Valves large (up to 33.2 mm high), semi-triangular, strongly curved, subequilateral, very inequivalved, right

valve strongly convex, left valve concave with beak area flattish; right valve with about 13 narrow and unnoded, primary radial ribs, becoming spinose posteriorly; interspaces (including sides of primary radial ribs) covered with up to seven closely spaced, finely beaded radial threads, one to two becoming spinose and of secondary-rib or nearly primary-rib strength on posterior half of valve; left valve with narrow and noded primary radial ribs, becoming spinose posteriorly, bifurcation common, about 16 primary ribs (including bifurcated ones), interspaces with very weak, finely noded and radial ribs. Valve interiors and hinge not seen.

Holotype.—UCMP 39883.

Paratype.—UCMP 39884.

Type locality.—UCMP loc. B-5688, Punta San Isidro, Baja California, Mexico (Alisitos Formation, Late Early Cretaceous).

Dimensions.—UCMP 39883, articulated specimen, height 33.2 mm, length 30.3 mm, thickness of double valves 15 mm. UCMP 39884, height 17.4 mm, length 12.4 mm.

Discussion.—Weathering has obscured much of the fine radial sculpture in the interspaces between the primary radial ribs on the available specimens of the new species, especially those that show the left valve.

Allison (1974) referred to the specimens of the new species as *Plicatula radiola* Lamarck (1819:185; Orbigny, 1843:683–685, pl. 463, figs. 1–7), which is known from rocks of Early Cretaceous age (Albian) of France. Comparisons between the Alisitos Formation specimens and two LACMIP collection specimens of *P. radiola* from Cotes Noires, Moeslains (Haute Marne), France, as well as comparisons with published illustrations, reveals that the new species is not *P. radiola*. The new species differs from this European species in the following features: right valve more convex and with narrower primary radial ribs, interspaces with closely spaced beaded to spinose radial sculpture rather than smooth; left valve primary rib interspaces with fine radial sculpture.

The new species is very similar to *Plicatula placunea* Lamarck (1819:186; Orbigny, 1843:682–683, pl. 462, figs. 11–18) from strata of Early Cretaceous age (Neocomian and Aptian) of France. The new species differs from *P. placunea* in the following features: right valve with narrower interspaces between the primary ribs, left valve with more radial ribs and nodes, and radial ribs and nodes on left valve more projecting rather than flattened out.

The strata at the type locality of the new species are part of the upper member of the Alisitos Formation, and Allison (1955, 1974) assigned these rocks to the middle Albian Stage.

Etymology.—The new species is named for the late Edwin C. Allison, who found the specimens of the new species.

Material examined.—One specimen from the type locality, and five others from the immediate vicinity of the type locality (two from UCMP loc. A-6278, and one from UCMP loc. A-9763).

Distribution.—Upper member of the Alisitos Formation at Punta San Isidro, Baja California, Mexico (UCMP locs. A-6278, A-6284, A-9763, B-5688).

Age.—Late Early Cretaceous (middle Albian).

PLICATULA MODJESKAENSIS new species

Figure 3.12–3.18

Diagnosis.—A small *Plicatula* with nearly equally convex valves sculpted by 9 to 13 fold-like, noded or spinose, radial ribs.

Description.—Valves small (up to 17.5 mm high), ostreiform, slightly curved, equivalved, slightly inequilateral, usually with same degree of low convexity; right valve showing small area of attachment in dorsal-posterior beak region; right valve com-

monly thickened in early stages of growth and slightly more convex than flattened left valve; shell sculpture of closely spaced primary, fold-like radial ribs (a few ribs bifurcated on some specimens), right valve with 9 to 13, rarely as many as 19, primary radial ribs (includes bifurcated ribs), left valve with 10 to 14 primary radial ribs (includes bifurcated ribs); primary ribs noded or spinose, strength increasing ventrally and posteriorly on some specimens; interior of left valve with closely spaced, small tubercles along anterior-ventral margin; hinge short, right valve with two stout teeth on each side of shallow resilifer.

Holotype.—LACMIP 8056.

Paratypes.—LACMIP 8057–8060.

Type locality.—LACMIP loc. 10888, Santa Ana Mountains, Orange County, southern California (Baker Canyon Member of the Ladd Formation, Early Late Cretaceous).

Dimensions.—LACMIP 8056, articulated specimen, height 12.8 mm, length 10.8 mm, thickness of double valves 3.7 mm. LACMIP 8057, right valve, height 13.6 mm, length 10.6 mm, thickness 4.3 mm. LACMIP 8058, partial right valve, height 11.8 mm, length (incomplete) 9.4 mm, thickness 3.2 mm. LACMIP 8059, partial right valve, height 15.0 mm, length (incomplete) 10.2 mm, thickness 3.7 mm. LACMIP 8060, left valve, articulated specimen, height 11.3 mm, length 10.6 mm, thickness of double valves 3.8 mm.

Discussion.—Ten of the available eleven specimens of *Plicatula modjeskaensis* are articulated. The specimens range in height from 6 to 17.5 mm. Preservation is moderately good to poor.

Plicatula modjeskaensis was found in the lower part of the Baker Canyon Member of the Ladd Formation at LACMIP loc. 10888 (=CIT loc. 981), in the northern part of the Santa Ana Mountains, Orange County, southern California (Figure 1). This locality is plotted (as CIT loc. 981) on a topographic base map in Saul and Bottjer (1982). The strata at CIT loc. 981 were deposited along a shoreline in warm, very shallow sublittoral water (Saul, 1982). The sedimentological details of the Baker Canyon Member indicate a fluctuating, moderate to high-energy, lower to upper shoreface paleoenvironment associated with a fan-delta setting (Cooper et al., 1982). A late Turonian age for the Baker Canyon Member is indicated by the ammonites *Subprionocyclus normalis* (Anderson, 1958) and *S. cf. Subprionocyclus neptuni* (Geinitz, 1849) (Saul, 1982).

Packard (1916, table 1) listed a *Plicatula* n. sp. from the Cretaceous of the Santa Ana Mountains but never described, named, or illustrated the species, and it cannot be equated with *Plicatula modjeskaensis*. Willis P. Popenoe collected and labelled, as *Plicatula* sp., specimens of *Plicatula modjeskaensis* but did not include them among the new species he described from the Santa Ana Mountains (Popenoe, 1937). He also did not include them on his check list of the Cretaceous fauna from the Santa Ana Mountains (Popenoe, 1942). Saul (1982, fig. 2) augmented this check list with additional localities, but, although mollusks from CIT loc. 981 are listed on both Popenoe's and Saul's check lists, no species of *Plicatula* are recorded from the Santa Ana Mountains.

The radial ribbing of *P. modjeskaensis* is of the type found in *Plicatula instabilis* Stoliczka, (1871, p. 445, pl. 34, figs. 3–14, not 19) from the Upper Cretaceous Arrialoor Group of India, in that the ribs appear fold-like.

Plicatula modjeskaensis is most similar to *Plicatula juncaensis* Squires (1987, p. 57–58, figs. 95–96) (Figure 4.11–4.13) from the middle lower Eocene ("Capay Stage") part of the Juncal Formation, Whitaker Peak area, Los Angeles County, southern California. The new species differs in having thinner and fewer radial ribs that are noded and/or spinose and in lacking secondary ribs.

The new species differs from *Plicatula variata* in having valves more nearly equally convex with spinose ribs. The number of ribs varies in both species, and a considerable overlap in rib count exists. Specimens with the greatest number of ribs are *P. modjeskaensis* and those with the lowest number of ribs are *P. variata*.

Two poorly preserved specimens of *Plicatula* cf. *P. modjeskaensis* were found in the Baker Canyon Member at LACMIP loc. 10883, which is 214 m (700 ft) south of the type locality of *P. modjeskaensis*. One of these specimens (hypotype LACMIP 8061) shows the hinge teeth of the right valve and is illustrated in Figure 3.19.

Etymology.—The new species is named for the hamlet of Modjeska just south of the type locality of the species.

Material examined.—Eleven specimens, all from the type locality, and two specimens, questionably included, from LACMIP loc. 10883.

Distribution.—The species is known only with certainty from its type locality in the lower part of the Baker Canyon Member of the Ladd Formation, Santa Ana Mountains, Orange County, southern California.

Age.—Early Late Cretaceous (late Turonian).

PLICATULA OSTREIFORMIS Stanton, 1896 Figure 4.5–4.10

Plicatula ostreiformis STANTON, 1896, p. 1038, pl. 63, figs. 5, 6; KEEN AND BENTSON, 1944, p. 103; MOORE, 1987, p. C5, pl. 1, figs. 1–3.

Plicatula ostreaformis Stanton. DICKERSON, 1914: 151, pl. 9, fig. 12; ZINSMEISTER AND PAREDES-MEJIA, 1988, table 1 on p. 15; [error for *ostreiformis*].

Ostrea buwaldana DICKERSON, 1914, p. 127, pl. 9, fig. 4; KEEN AND BENTSON, 1944, p. 74.

Acuostrea idriaensis fettkei (Weaver). MOORE, 1987, p. 30 (in part), fig. 5 (only).

Original description.—"Shell large, irregularly ovate in outline, but varying considerably in this respect; valves subequal, the right one being usually slightly convex and the left flattened or a little concave in the middle; test unusually thick; surface with obscure radiating plications and irregular pits. An average specimen measures 52 mm in length, 39 mm in breadth, and 19 mm in greatest convexity of the two valves united. Internal casts show impression of the characteristic hinge of *Plicatula*" (Stanton, 1896, p. 1038).

Type specimens.—Syntypes of *Plicatula ostreiformis* USNM 157838. Holotype of *Ostrea buwaldana* UCMP 11719.

Type locality.—Of *P. ostreiformis*: 1.5 km (1 mi.) southeast of Lower Lake, NE ¼, T12N, R7W, Lake County, California (Martinez Formation, early Paleocene). Of *O. buwaldana*: UCMP loc. 790, Lower Lake, Lake County, California (Martinez Formation, early Paleocene).

Discussion.—This unusual species has a maximum size of 52 mm in height and represents the largest known *Plicatula* in the fossil record of California and Baja California. Most available specimens, including the syntypes figured in Moore (1987, pl. 1, figs. 1–3) are partially exfoliated and show virtually no sculpture. Partially exfoliated specimens in the LACMIP collection from LACMIP loc. 7047 show about six broad, low, dichotomous radial ribs, which are commonly most obvious near the ventral margin of the valves. Where not exfoliated, the broad ribs bear narrow radiating cords. The radial ribs, and in some specimens both valves, are thrown into broad concentric undulations by apparent growth checks. Both valves are convex, that of the attached right valve being the more variable, ranging from scarcely more than that of the upper valve to at least twice as deep. Unlike the Cretaceous species, *P. variata* and *P. mod-*