

BIVALVE MOLLUSCAN PALEOECOLOGY OF NORTHERN EXPOSURES OF THE MARINE NEOGENE IMPERIAL FORMATION IN RIVERSIDE COUNTY, CALIFORNIA

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INTRODUCTION

The marine Imperial Formation was deposited at the head of the proto-Gulf of California during the latest Miocene through late(?) Pliocene time. The formation crops out discontinuously northward from just south of the California-Mexico border to San Geronio Pass, Riverside County, California. Exposures of the Imperial Formation in Riverside County occur along the San Andreas-Banning fault zone. Important exposures occur at Lions Canyon, Super Creek, Garnet Hill, Edom Hill and Willis Palm (fig. 1). The faunas from Super Creek, Garnet Hill and Willis Palm each represent different environments and form the basis for this note. The Imperial Formation in Riverside County attains a maximum thickness of 105 m and is divided into two members separated by a time transgressive boundary from north to south.

The lower, Latrania Sand Member (Keen and Bentson, 1944), whose type section is in Imperial County, is generally composed of coarse- to medium-grained sandstone with scattered conglomeratic beds; it attains a maximum thickness of 30 m in Riverside County. The molluscan assemblage from the Latrania Sand Member in Riverside County is characterized by species that lived in a euhaline, moderate- to high-energy, intertidal(?) to inner shelf, rocky to sandy habitat. Taxa that commonly occur in Riverside County include *Spondylus victoriae* (Sowerby), *Pycnodonte heermanni* (Conrad) [= "*Ostrea*" *heermanni* Conrad], *Dendostrea angelica* (Rocheburne), and *Argopecten* spp. (pl. 1). ✓

The unnamed, upper member of the Imperial Formation is about 75 m thick in Riverside County. In this area it represents a low- to moderate-energy, outer shelf facies and is composed of medium- to fine-grained sandstone and siltstone. Characteristic bivalve mollusks in this member in Riverside County include *Cyclopecten* sp. cf. *C. pernomus* (Hertlein), *Dendostrea? vespertina* (Conrad), and *Anomia peruviana* d'Orbigny (pl. 1). ✓

PALEOECOLOGY

Super Creek Area

Both members of the Imperial Formation are exposed along Super Creek. The Latrania Sand Member occurs in small discontinuous synclines (fig. 2), and appears to have been deposited in small pocket beaches in rocky headlands. The outcrops are characterized by abundant *Spondylus victoriae* and *Dendostrea angelica* that are found attached to large clasts in conglomeratic stringers. Bernard (1983) reports *D. angelica* in water depths of 1 to 5 m and *S. victoriae* from 10 to 40 m. Thus the Latrania Sand Member along Super Creek was probably deposited in shallow subtidal depths that deepened upsection to between 10 and 40 m at the top of the member. These beds are overlain by a 70- cm thick "worm tube" marl at the top of the Latrania Sand Member. The environment of deposition of the marl was not determined because of the poor preservation of its fossils.

The Latrania Sand Member is overlain by medium- to fine-grained sandstone and siltstone of the unnamed upper member. About 10 m above the top of the Latrania Sand is a bed of *Atrina* n. sp. preserved in life position. *Atrina* is found in water depths from 1 to 125 m in the eastern Pacific, but only *A. texta* Hertlein & Strong, is reported to occur below 30 m. Benthic foraminifers from this bed suggest inner neritic water depths (0-50 m) (K. A. McDougall, written commun., 1981). Together these data suggest water depths of less than 50 m for the lower part of the unnamed upper member of the Imperial Formation. Near the top of the upper member, *Cyclopecten* sp. cf. *C. pernomus* and many shell fragments have been concentrated into small shell lag deposits, possibly by currents. Water depth during deposition of this unit is unclear, but the

occurrence of *C. sp. cf. C. pernomus* limits the depth to 355 m (Bernard, 1983). Benthic foraminifers throughout the upper member indicate that water depths increase to middle and outer neritic depths (50-150 m) near the top of the formation (K. A. McDougall, written commun., 1981).

In the Super Creek area, the Imperial Formation is overlain by medium- to coarse-grained sands and conglomeratic beds of the Painted Hill Formation, previously interpreted as alluvial fan deposits by Allen (1957). The interfingering of the Painted Hill Formation with neritic silts of the Imperial Formation indicates that the base of the Painted Hill Formation probably is not of alluvial fan origin.

Garnet Hill Area

About 17 m of the Latrania Sand Member are poorly exposed on Garnet Hill. These beds are composed of coarse- to fine-grained sandstone with abundant gneissic and marble clasts as much as 2 m in diameter. Some of these clasts have been bored by lithophagid bivalves (identified by G. L. Kennedy, oral commun., 1984). Also present on some of the clasts are poorly preserved specimens of *Spondylus sp.* and *Dendostrea sp. cf. D. angelica*. *Pycnodonte Heermanni* is abundant as float on the south slope of Garnet Hill. These species, although inconclusive as to their environmental parameters, suggest shallow water depths with at least some areas of exposed rocks.

Willis Palm Area

The Imperial Formation at Willis Palm consists of about 53 m of generally fine-grained sandstone and siltstone. Three shell beds are exposed in this section. The first contains unidentifiable mollusk fragments, crab chelipeds, and the gastropod *Melampus sp.*, which suggests a salt marsh environment. About 2 m above this bed is a 2-m-thick oyster bioherm composed of flat to slightly plicate *Dendostrea? vespertina*. This bioherm suggests a moderately shallow bay or lagoonal environment. The third shell bed, about 15 m above the base of the formation, is 20 cm thick and composed of abundant well preserved shells. This bed is characterized by the bivalve mollusks *Leptopecten palmeri* (Dall), *Cyclopecten sp. cf. C. pernomus*, *Cyrtopleura costata* (Linnaeus), and abundant corbulids. These species suggest shallow water depths between 1 and 90 m. Benthic foraminifers from this section indicate shallow water (K. A. McDougall, written commun., 1984). Fossils from throughout the Willis Palm section indicate that water depths increased from very shallow inner neritic (< 10 m) at the first shell bed to a maximum depth of inner neretic (10 - 50 m) just above the top shell bed, and then shallowed to less than 10 m at the top of the formation.

CONCLUSIONS

Other exposures of the Imperial Formation are present in Riverside County but were either inaccessible during the present study (Lions Canyon) or contained such a meager fauna that paleoecological analysis was impossible (Edom Hill).

The sections at Super Creek and Garnet Hill appear to be older than those exposed at Willis Palm. These relative-age estimates are based on biostratigraphic data and on an unpublished K/Ar date on a basalt flow in the Painted Hill Formation along Super Creek (J. C. Matti, personal commun., 1984). The Super Creek section seems to represent a deepening basin: the intertidal or shallow subtidal rocky shore facies of the Latrania Sand Member at the base of the formation grades into middle and outer neritic fine-grained continental-shelf facies of the upper member at the top of the formation. Sediments exposed at Garnet Hill appear to represent the same environment as represented by the Latrania Sand Member at Super Creek. The Willis Palm section represents a transgressive-regressive sequence starting with a salt marsh environment, which grades upsection into a shallow lagoon or bay, characterized by an oyster bioherm. This is followed further upsection by a slightly deeper, possibly open marine environment, which again changed to shallow or possibly intertidal depths at the top of the formation.

LITERATURE CITED

- Allen, C. R., 1957. San Andreas fault zone in San Gorgonio Pass, southern California. *Bulletin of the Geological Society of America*, 68(3):315-350, figs. 1-3, pls. 1-6.
- Bernard, F. R., 1983. Catalogue of the living Bivalvia of the eastern Pacific Ocean: Bering Strait to Cape Horn. *Canadian Special Publication of Fisheries and Aquatic Sciences*, 61: 1-102.
- Keen, A. M. & Herdis Bentson, 1944. Checklist of California Tertiary marine mollusks. *Geological Society of America, Special Paper 56*: 1-280.

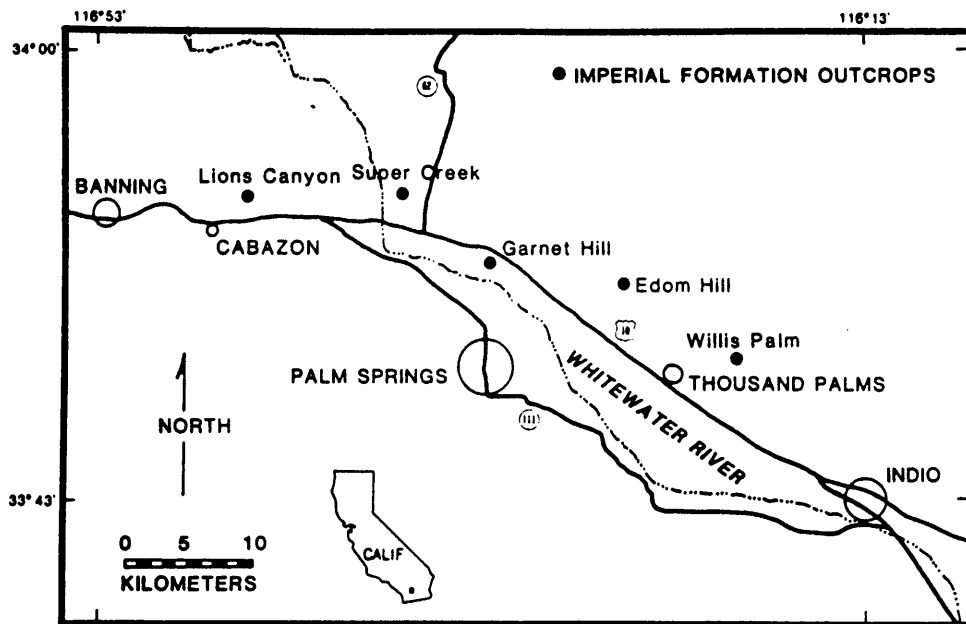


Figure 1. Index map showing localities of the Imperial Formation in the study area.

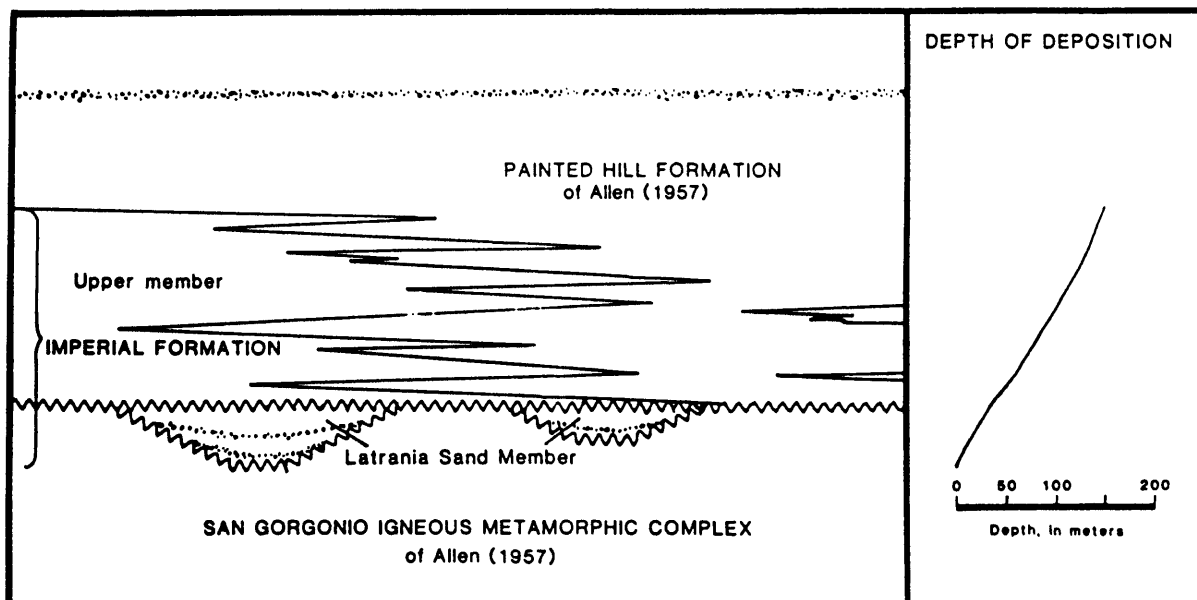


Figure 2. Stratigraphic relationships of the unnamed upper member and the Latrania Sand Member of the Imperial Formation, and their inferred depths of deposition along Super Creek, Riverside County, California.

CIT187 = LACMIP 16204
 CIT 192 = LACMIP 16347
 UCR 8595 = LACMIP 16205

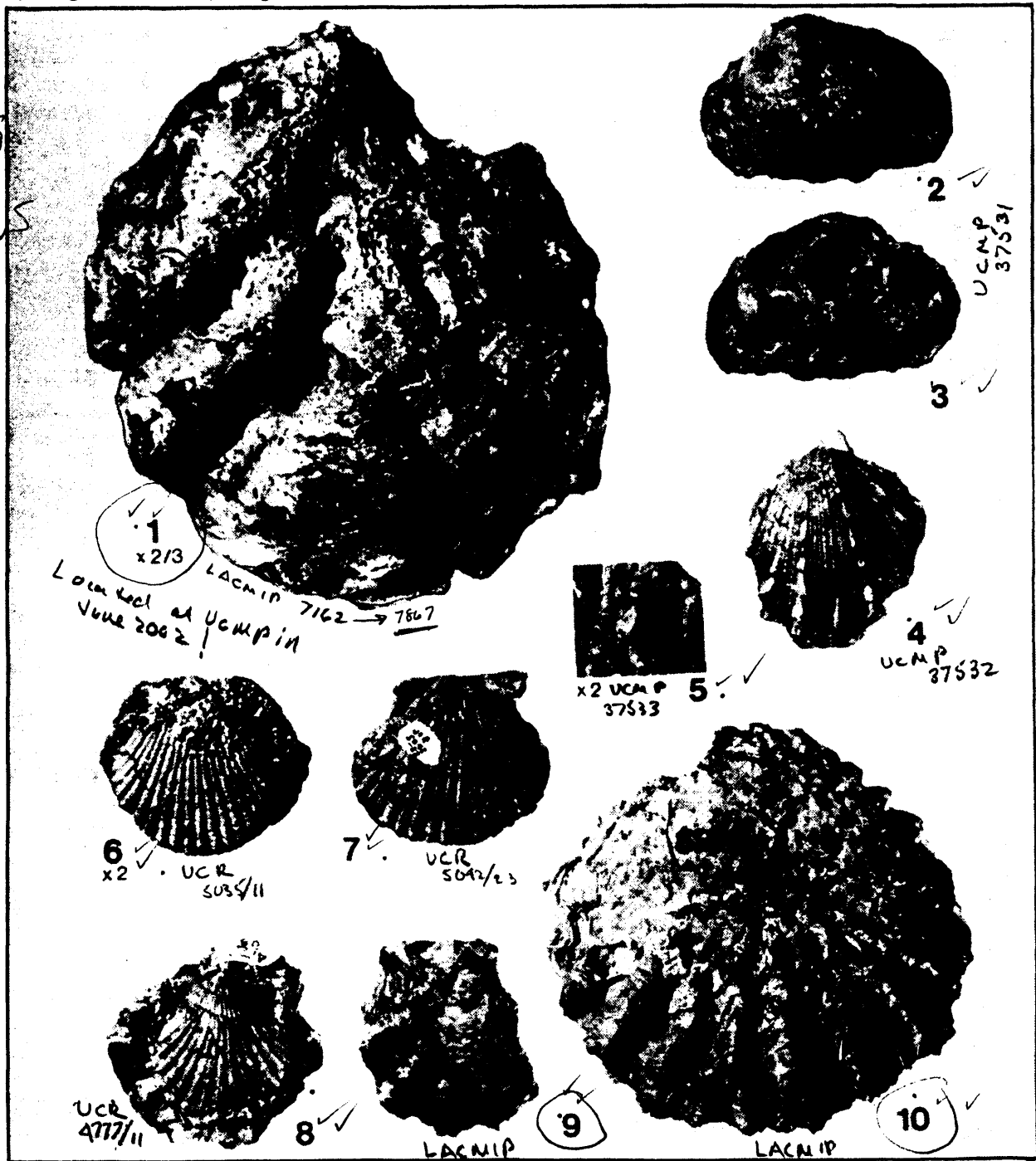
PLATE 1 (All figures x1 except as indicated)

Figure ① *Pycnodonte (Pycnodonte?) heermanni* (Conrad, 1855). Left valve. LACMIP 7162; length 131 mm, height 148 mm. sp. CIT loc. 192. Figures 2 and 3. *Anomia peruviana* d'Orbigny, 1846. Articulated valves. UCMP 37531; length 49.9 mm, height 35.1 mm. UCMP loc. A-1417. Figure 4. *Spondylus victoriae* Sowerby, 1859. Right valve. UCMP 37532; length 35.4 mm, height 39.6 mm. UCMP loc. A-3188. Figure 5. *Cyclopecten* sp. cf. *C. pernomus* (Hertlein, 1935). Right valve. UCMP 37533; length 4.4 mm, height 4.8 mm. UCMP loc. A-1407. Figure 6. *Argopecten* sp. cf. *A. mendenhalli* (Arnold, 1906). Left valve?. UCR 5035/11; length 17.1 mm, height 18.1 mm. UCR loc. 5035. Figure 7. *Argopecten sverdrupi* (Durham, 1950). Right valve. UCR 5042/23; length 39.1 mm, height 34.6 mm. UCR loc. 5042. Figure 8. *Leptopecten (Leptopecten) palmeri* (Dall, 1897). Left valve. UCR 4777/11; length 26.3 mm, height 27.6 mm. UCR loc. 4777. Figure ⑨ *Dendostrea? vespertina* (Conrad, 1854). Right valve. LACMIP 7163; length 31.1 mm, height 38.1 mm. CIT loc. 187. Figure ⑩ *Dendostrea angelica* (Rocheburne, 1895). Left valve. LACMIP 7164; length 79.5 mm, height 80.5 mm. UCR loc. 8595.

NEW
 TYPE
 NUMBERS
 FOR 3
 SPECIMENS

7867
 7868
 7869

HF
 14 JUNE 06
 EXTENDED
 11 JULY 06



①
 x2/3
 LACMIP 7162 → 7867
 Loc. loc. at UCMP in
 June 2002!

UCMP
 37531

UCMP
 37532

x2 UCMP
 37533

x2 UCR
 5035/11

UCR
 5042/23

UCR
 4777/11

LACMIP
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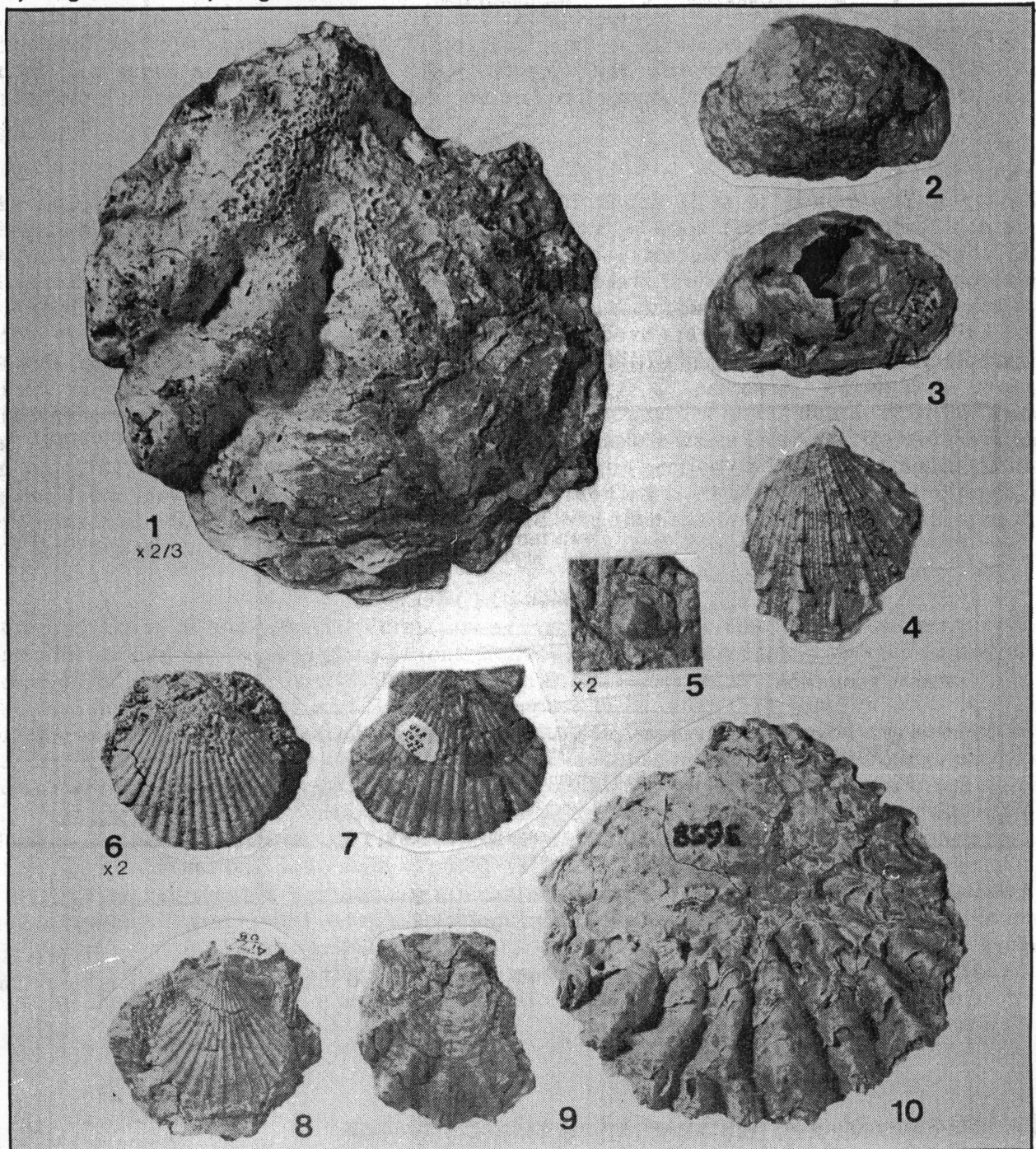
LACMIP
 7164

'missing' → 7868

'missing' → 7869

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Figure 1. *Pycnodonte (Pycnodonte?) heermanni* (Conrad, 1855). Left valve. LACMIP 7162; length 131 mm, height 148 mm. sp. CIT loc. 192. Figures 2 and 3. *Anomia peruviana* d'Orbigny, 1846. Articulated valves. UCMP 37531; length 49.9 mm, height 35.1 mm. UCMP loc. A-1417. Figure 4. *Spondylus victoriae* Sowerby, 1859. Right valve. UCMP 37532; length 35.4 mm, height 39.6 mm. UCMP loc. A-3188. Figure 5. *Cyclopecten* sp. cf. *C. pernorus* (Hertlein, 1935). Right valve. UCMP 37533; length 4.4 mm, height 4.8 mm. UCMP loc. A-1407. Figure 6. *Argopecten* sp. cf. *A. mendenhalli* (Arnold, 1906). Left valve?. UCR 5035/11; length 17.1 mm, height 18.1 mm. UCR loc. 5035. Figure 7. *Argopecten sverdrupi* (Durham, 1950). Right valve. UCR 5042/23; length 39.1 mm, height 34.6 mm. UCR loc. 5042. Figure 8. *Leptopecten (Leptopecten) palmeri* (Dall, 1897). Left valve. UCR 4777/11; length 26.3 mm, height 27.6 mm. UCR loc. 4777. Figure 9. *Dendostrea? vespertina* (Conrad, 1854). Right valve. LACMIP 7163; length 31.1 mm, height 38.1 mm. CIT loc. 187. Figure 10. *Dendostrea angelica* (Rocheburne, 1895). Left valve. LACMIP 7164; length 79.5 mm, height 80.5 mm. UCR loc. 8595.



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