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MOLLUSCAN PALEONTOLOGY OF THE LOWER EOCENE MANIOBRA FORMATION, OROCOPIA MOUNTAINS, SOUTHERN CALIFORNIA

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ABSTRACT

The middle lower Eocene Maniobra Formation, Orocopia Mountains, Riverside County, southern California, contains 48 macrofossil taxa that are identifiable to the species level. These taxa, which are illustrated herein, include 32 species of gastropods, 11 species of bivalves, and one species each of colonial coral, solitary coral, brachiopod, polychaete worm, and scaphopod. The fossils are mostly small-sized fragments and are concentrated in lenses. They are shallow-marine species that were transported a short distance basinward into slope and submarine-canyon environments.

The Maniobra Formation macrofossils are indicative of the middle lower Eocene "Capay Stage" and indicative of widespread warm-water conditions. Several of the gastropods show Old World affinities. Most of the Maniobra Formation macrofossil species have widespread distribution elsewhere in early Eocene faunas from the Pacific coast of North America.

INTRODUCTION

The Maniobra Formation crops out in the northeastern Orocopia Mountains, Riverside County, southeastern California (Fig. 1). The formation is the only known marine Eocene exposure south of the San Emigdio and western Tehachapi Mountains and east of the San Andreas fault in southern California. Since its discovery in the late 1950's, the formation has been a key in palinspastic reconstructions along the San Andreas fault. This paper, however, is the first detailed macropaleontologic investigation of the formation.

PREVIOUS PALEONTOLOGICAL INVESTIGATIONS

In 1959, Crowell and Susuki formally named the Maniobra Formation and presented a preliminary list of some of its macrofossils, as well as illustrations of a few of the species. Advocate (1983) presented a faunal list but did not illustrate any species, and Squires and Advocate (1986) described and illustrated several new species of mollusks from the formation. Advocate et al. (1988) only made general reference to some of the more age-diagnostic Maniobra mollusks in their report on the details of the stratigraphy and sedimentology of the formation.

METHODS

The macrofossils examined in this present study came primarily from collections made by Advocate (1983) and by collections made by the author. About 500 specimens were collected by Advocate from 17 localities. Fossils collected by him are stored in the paleontology collection of the Department of Geological Sciences, California State University, Northridge (CSUN). During this present study, it was found that only 13 of Advocate's 17 localities yielded identifiable species. These 13 localities represent the focus of this report. Their locations and relative stratigraphic positions are shown in Figure 2.

About 500 additional specimens were collected by the author from some of Advocate's richest localities (especially CSUN 662, 674, and 676). These fossils are also stored at CSUN.

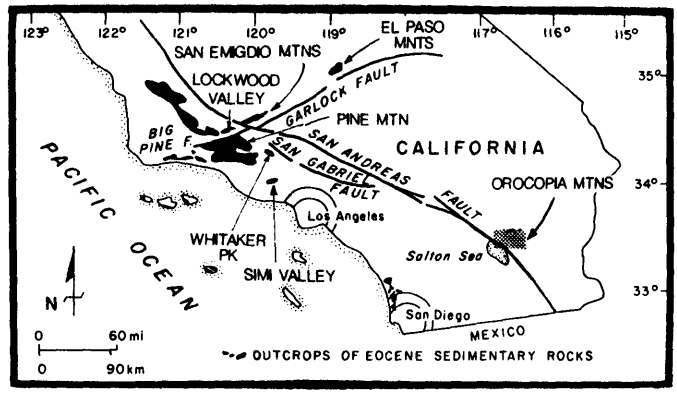

Figure 1. Index map of southern California showing major faults, Eocene outcrops, and study area. Modified from Advocate et al. (1988).

About 100 specimens were collected by Crowell and Susuki (1959, pl. 1) from 13 localities. Their distribution is very close to the localities of Advocate (1983). Most of their specimens are from locality F, which is the same as locality CSUN 662. Some of their better preserved specimens from this locality are figured in this report. Their fossils were originally stored at the University of California, Los Angeles (UCLA), but the UCLA paleontology collection is now housed in the Los Angeles County Museum of Natural History Invertebrate Paleontology collection (LACMIP).

All the photographed specimens used in this present report are housed at LACMIP. The identifications of the Maniobra Formation macrofossils were based on published figures and descriptions and comparisons with selected type and non-type specimens deposited at CSUN and LACMIP.

In terms of microfossil investigations of the Maniobra Formation, Cole (1958) discussed the presence of the large benthic foraminifers *Pseudophragmina psila* (Woodring) and *Asterocyclina aster* (Woodring). Johnston (1961) described the benthic foraminiferal assemblages from the lower mudstone beds. Advocate (1983) and Advocate et al. (1988) described some of the benthic, planktonic, and calcareous nannofossils from the formation.

GEOLOGIC SETTING AND DEPOSITIONAL ENVIRONMENTS

The Orocopia Mountains area is postulated to have been in the eastern part of the Santa Lucia-Orocopia allochthon (Vedder et al. 1983, fig. 9). According to their hypothesis, this allochthon was accreted to the southern California region in latest Paleocene or earliest Eocene time. A high-relief area that formed along the eastern margin of the allochthon was subsequently eroded, and basins, like the one in which the Maniobra Formation accumulated, began to be infilled.

The Maniobra Formation has a maximum thickness of 1,450

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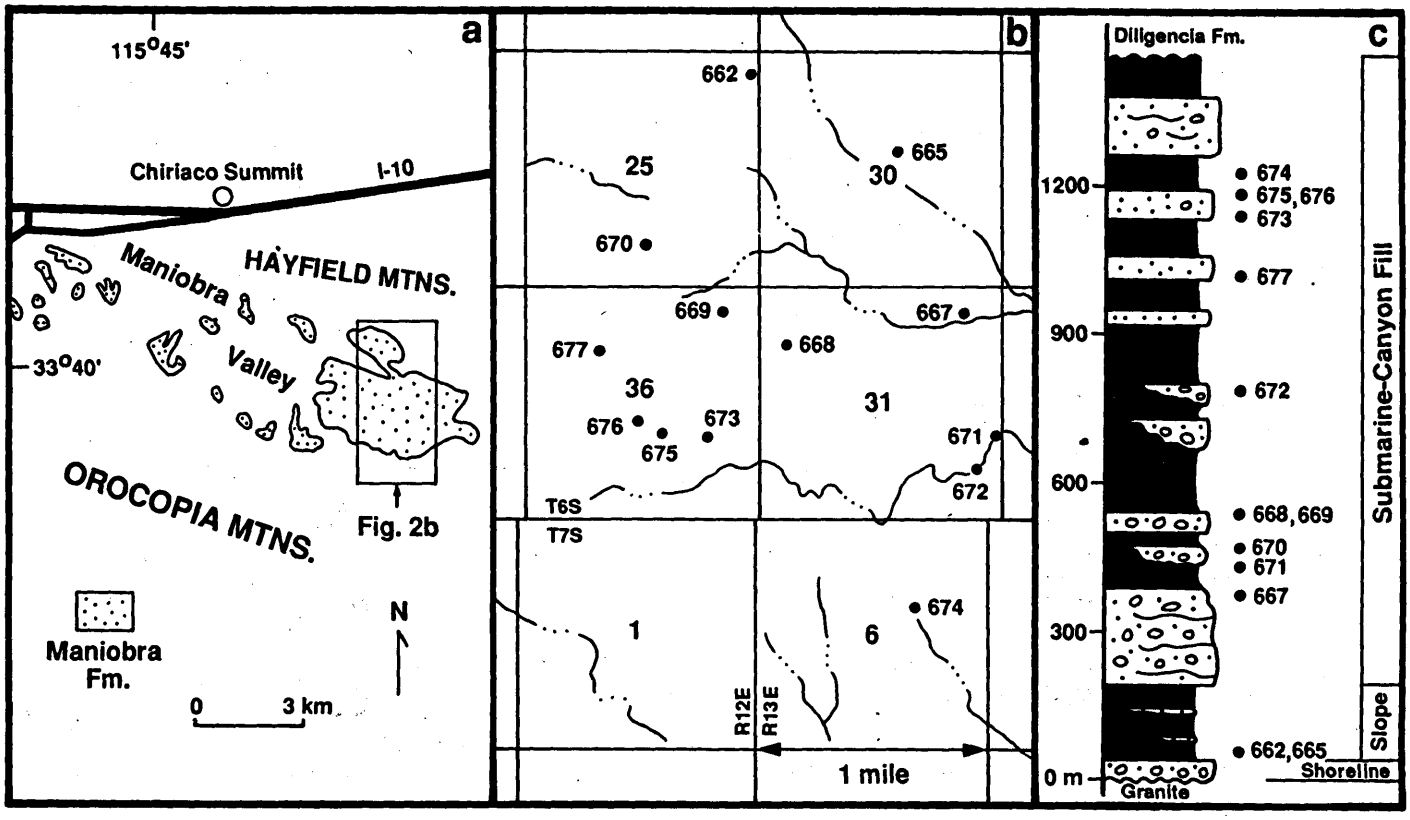

Figure 2. a) Index map showing outcrops of Maniobra Formation and area of enlargement shown in Fig. 2b; b) Location of CSUN macrofossil localities; c) Simplified and generalized stratigraphic column of the Maniobra Formation showing stratigraphic position of each macrofossil locality.

m. At the base there is a 46 m-thick, shoreline unit that consists of conglomerate and sandstone. It is overlain by 150 m of slope mudstone. The shoreline unit and the slope mudstone make up the northern exposures of the formation. The slope mudstone is overlain by 1,250 m of submarine-canyon fill that consists of mudstone, sandstone, and conglomerate. This submarine-canyon fill accounts for about 85 percent of the formation and makes up the southern exposures of the formation. The submarine-canyon-fill deposits accumulated in a fault-controlled submarine canyon during an overall sea-level rise. The canyon is incised into the shoreline unit and the slope deposits, as well as into the Upper Cretaceous granitic basement. The canyon was a least 4 km wide, 15 km long, and extended from the shoreline to bathyal depths within a lateral distance of 3 km. The canyon has a narrow, asymmetric V-shaped head oriented obliquely to the ancient shoreline and a broad U-shaped body oriented roughly parallel to the ancient shoreline. The fault-bounded northern and eastern margins of the canyon were steep. Sediment transport was chiefly down the canyon by westerly directed sediment-gravity flows, as well as by slumping and rockfalls along the canyon sides. Some of the clasts in the initial conglomerate deposits within the submarine canyon are extremely large (up to 5 m). Macrofossils are shallow-marine forms that lived adjacent to the submarine canyon and were transported basinward into the bathyal depths of the slope and submarine canyon (Advocate et al., 1988).

Squires and Advocate (1986) and Advocate et al. (1988) reported that the Maniobra Formation was deposited in tropical to subtropical conditions of normal salinity based on mollusks, planktonic foraminifera, and radiolaria. These conclusions are confirmed in this present study. In addition, specimens of the colonial scleractinian coral *Astrocoenia dilloni* are also present in the formation. This species has been found in coral reef(?)-influenced deposits of the Eocene Bateque Formation in Baja California Sur, Mexico (Squires and Demetrion, in press).

The Maniobra Formation is unconformably overlain by nonmarine beds of the lower Miocene Diligencia Formation (Advocate et al., 1988).

MACROFOSSIL PALEONTOLOGY

Only trace fossils were found in the shoreline deposits of the Maniobra Formation because the high-energy, reworking processes that existed there (Advocate et al., 1988) removed any body fossils. Arenaceous foraminifera are fairly common in the slope mudstones, but macrofossils are uncommon except within a few discontinuous, thin sandy mudstone lenses like at locality 662. This locality is the richest macrofossil bed in the formation and yielded 28 species (Table 1). There are abundant specimens of the gastropod *Turritella uvasana hendoni* s.l., the bivalve *Ostrea haleyi*, and the brachiopod *Kingena? simiensis*. Nearly all the specimens of *T. u. hendoni* s.l. are fragments of the upper spire, but their delicate spiral ribbing is unabraded. All of the specimens of *O. haleyi* are single valves and most are fragmentary. Nearly all of the *Kingena?* are articulated. There are also fairly common specimens of *Glyptoactis* n. sp.? at locality 662. They are all small sized and mostly closed valved. Nearly all of the fossils at locality 662 were interpreted as having undergone post-mortem transport. The closed-valved brachiopods and bivalves, however, were interpreted as having been transported while alive (Advocate et al., 1988).

Macrofossils are locally common in the submarine-canyon-fill deposits in the upper part of the formation (e.g., localities 673, 675, 676, 677). The fossils are in lenses of conglomerate, and the lenses are about 50 cm in thickness and 20 to 40 m in lateral extent. Clasts are poorly sorted and angular. Some granite clasts were 13 cm in length (small cobble). The macrofossils are mostly *Turritella andersoni* and they usually make up about 15 percent of the conglomerate. The lenses show graded bedding and the largest specimens of *Turritella andersoni* are in the

TAXA CSUN LOCALITIES:	662	665	667	668	669	670	671	672	673	674	675	676	677
CNIDARIA													
Astrocoenia dilloni Durham	x								?				
Turbinolia dickersoni Nomland										x			
BRACHIOPODA													
Kingena? simiensis Waring	x												
ANNELIDA													
Rotularia n. sp.?	x												
SCAPHOPODA													
Dentalium stramineum? Gabb												x	
GASTROPODA													
Amaurellina caleocia Vokes	x												
Arene mcleani Squires, 1987	x												
Bittium cf. B. preussi (Hanna)	x												
Caloreabama dilleri lineata (Gabb)										x			
Calyptraea diegoana (Conrad)										x			
Campanile dilloni (Hanna & Hertlein)			x	x	x								
Certhiopsis aff. C. llajasensis Squires	x												
Chedevillia saltonensis Squires & Advocate	x												
Clavilithes tabulatus (Dickerson)	x					x							
Conus hornii umpquaensis Turner										x			
Cylichnina tantilla (Anderson & Hanna, 1925)	x									x			
Domenginella aff. D. claytonensis (Gabb)	x												
Ectinochilus (Vaderos) cf. E. (V.) elongata (Weaver)	x												
Eocernina hannibali (Dickerson)	x		x		?		x	x	x		x		
Eocypraea? maniobraensis Squires & Advocate	x												
Favartia? sp.										x			
Ficopsis remondii crescentensis? Weaver & Palmer	x												
Galeodea cf. G. gallica Wrigley	x												
Homalopoma aff. H. wattsi (Dickerson)										x			
?Loxotrema turritum Gabb							x						
Lyria andersoni Waring											x		
Lyriscapha lajollaensis (Hanna)								x					
Pachycrommium clarki (Stewart)								x	x	?	x	x	
Phalium (Semicassis) louella Squires & Advocate	x	x											
Pleurofusia fresnoensis (Arnold)	x												
Surculites mathewsonii (Gabb)							x						
Turritella andersoni Dickerson							x		x	x	x	x	x
Turritella buwaldana Dickerson	x									x	x		
Turritella meganosensis protumescens Merriam & Turner							x						
Turritella uvasana hendoni s.l. Merriam	x												
Velates perversus (Gmelin)		x											
Volutilithes orocopiaensis Squires & Advocate	x												
BIVALVIA													
Acanthocardia (Schedocardia) brewerii (Gabb)							x			x			x
Acila (Truncacila) decisa (Conrad)										x			
Callista (Costacallista) hornii vokesi Squires									x	x	x	cf.	
Corbula (Caryocorbula) cf. C. (C.) dickersoni Weaver & Palmer	x											x	
Crassatella sp. indet.								x					
Glossus (Meiocardia) susukii Squires & Advocate	x									x			
Glycymeris (Glycymerita) sagittata? (Gabb)	x									x			
Glyptoactis n. sp.?	x												
Glyptoactis (Claibornicardia) domenginica (Vokes)										x		x	
Ostrea haleyi Hertlein	x												
Pitar (Lamelliconcha) joaquinensis Vokes							cf.			x			
Spondylus cf. S. carlosensis Anderson	x									x	x	x	
Venericardia (Pacificor) sp. indet.	x							x	x	x	x	x	

Table 1. Check list of Maniobra Formation macrofossil taxa identifiable to generic or species/subspecies level.

basal parts of the lenses.

Preservation of the Maniobra macrofossils ranges from fair to poor. Many of the fossils are of small size, and most of the larger ones (e.g., *Campanile dilloni*) are fragmental. At localities 673, 675, 676, and 677, in the upper part of the formation, there are abundant specimens of *T. andersoni*. Most of these are in conglomerate beds and are badly weathered. With diligent collecting, fairly well preserved specimens can be found and these show the spiral ribbing characteristic of *T. andersoni*. Crowell and Susuki (1959) and Squires and Advocate (1986) collected from the general area of these four localities and reported the presence of *T. andersoni lawsoni*. Their specimens are actually weathered specimens of *T. andersoni*.

A total of 67 taxa, 59 (88 percent) of which are mollusks,

Plate 1

Figures 1-26. Maniobra Formation corals, brachiopod, polychaete worm, scaphopod, and gastropods identifiable as to species or subspecies. Figs. 1-3, corals. Fig. 4, brachiopod. Figs. 5-6, polychaete worm. Fig. 7, scaphopod. Figs. 8-26, gastropods.

1. *Astrocoenia dilloni* Durham, 1942, dorsal view, x3.8, maximum width of field 14 mm, LACMIP hypotype 11446, CSUN loc. 662.
2-3. *Turbinolia dickersoni* Nomland, 1916. (2) dorsal view, x10.7, diameter 1.5 mm, LACMIP hypotype 11447, CSUN loc. 674; (3) lateral view, x6.4, height 4.5 mm, LACMIP hypotype 11448, CSUN loc. 674.
4. *Kingena? simiensis* Waring, 1917, brachial valve of a closed-valved specimen, x2, length 19 mm, LACMIP hypotype 11449, LACMIP loc. 23779 = CSUN loc. 662.
5-6. *Rotularia* n. sp.?, (5) dorsal and (6) side views, x3.8, greatest diameter 9 mm, LACMIP hypotype 11450, LACMIP loc. 23779 = CSUN loc. 662.
7. *Dentalium stramineum*? Gabb, 1864, partial specimen, side view, x2.5, length 15 mm, LACMIP hypotype 11451, CSUN loc. 676.
8. *Arene mcleani* Squires, 1987, abapertural view, x10, height 2 mm, width 3 mm, LACMIP hypotype 11452, CSUN loc. 662.
9. *Homalopoma* aff. *H. wattsi* (Dickerson, 1916), apertural view, x5, height 6 mm, width 6 mm, LACMIP hypotype 11453, CSUN loc. 674.
10-11. *Velates perversus* (Gmelin, 1791), LACMIP hypotype 11454, CSUN loc. 665, (10) abapertural view showing spiral surface, x1.3, height 28.5 mm; (11) apertural view, x1.2, height 28.5 mm.
12. *Turritella andersoni* Dickerson, 1916, partial specimen, apertural view, x2.9, height 15 mm, width 8 mm, LACMIP hypotype 11455, CSUN loc. 676.
13. *Turritella meganosensis protumescens* Merriam and Turner, 1937, partial specimen, abapertural view, x1.6, height 19 mm, width 18 mm, LACMIP hypotype 11456, CSUN loc.671.
14. *Turritella buwaldana* Dickerson, 1916, partial specimen, abapertural view, x2.3, height 20 mm, width 8 mm, LACMIP hypotype 11457, CSUN loc. 674.
15. *Turritella uvasana hendoni* s.l. Merriam, 1941, abapertural view, x1.8, height 30 mm, width 11 mm, LACMIP hypotype 11458, CSUN loc. 662.
16. ?*Loxotrema turritum* Gabb, 1868, abapertural view, x1.5, height 32 mm, width 13 mm, LACMIP hypotype 11459, CSUN loc. 671.
17. *Bittium* cf. *B. preussi* (Hanna, 1924), abapertural view, x7.4, height 5 mm, width 2 mm, LACMIP hypotype 11460, CSUN loc. 662.
18. *Campanile dilloni* (Hanna and Hertlein, 1949), right side view, x0.5, height 185 mm, LACMIP hypotype 7165, CSUN loc. 668.
19. *Cerithiopsis* aff. *C. llajasensis* Squires, 1984, abapertural view, x4.5, height 10.5 mm, width 4.5 mm, LACMIP hypotype 11461, LACMIF loc. 23779.
20. *Calyptraea diegoana* (Conrad, 1855), side view, x5, height 3 mm, width 7 mm, LACMIP hypotype 11462, CSUN loc. 674.
21. *Ectinochilus* (*Vaderos*) cf. *E.* (*V.*) *elongata* (Weaver, 1912), left side view, x2.4, height 22 mm, LACMIP hypotype 11463, LACMIP loc. 23779 = CSUN loc. 662.
22. *Chedevillia saltonensis* Squires and Advocate, 1986, apertural view, x2, height 26 mm, width 12 mm, UCLA holotype 28987, LACMIP loc. 23779 = CSUN loc. 662. LACMIP hypotype 10564
23. *Eocypraea? maniobraensis* Squires and Advocate, 1986, apertural view, x1.3, height 39 mm, width 23 mm, UCLA holotype 48431, LACMIP loc. 23779 = CSUN loc. 662. LACMIP holotype 10566
24. *Eocernina hannibali* (Dickerson, 1914), apertural view, x1.1, height 45 mm, width 37 mm, LACMIP hypotype 11464, LACMIP loc. 23779 = CSUN loc. 662.
25. *Pachycrommium clarki* (Stewart, 1927), partial specimen, left side view, x1.3, height 33 mm, LACMIP hypotype 11465, CSUN loc. 672.
26. *Amaurellina caleocia* Vokes, 1939, apertural view, x4.8, height 9 mm, width 7 mm, LACMIP hypotype 11466, LACMIP loc. 23779 = CSUN loc. 662.

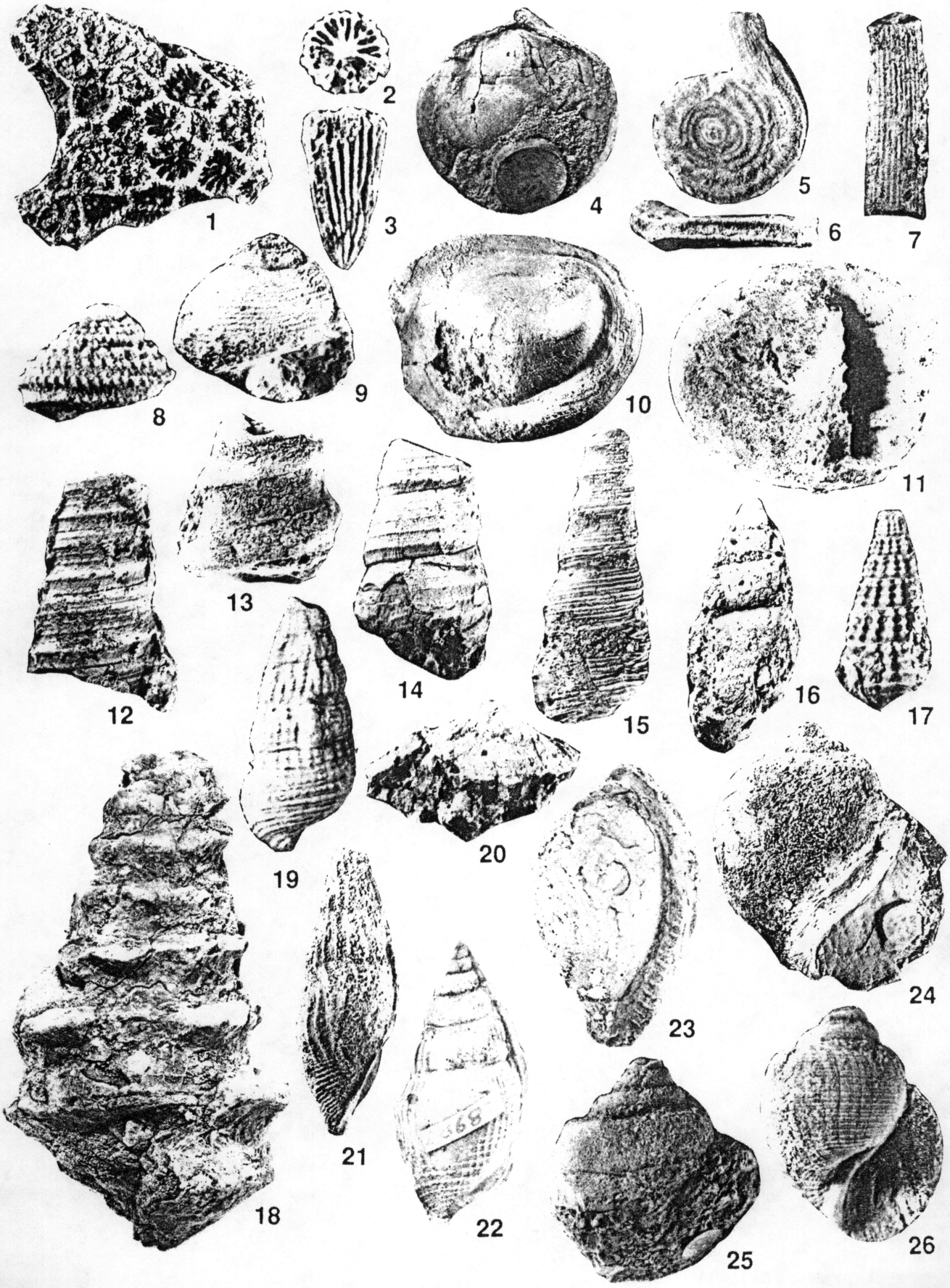
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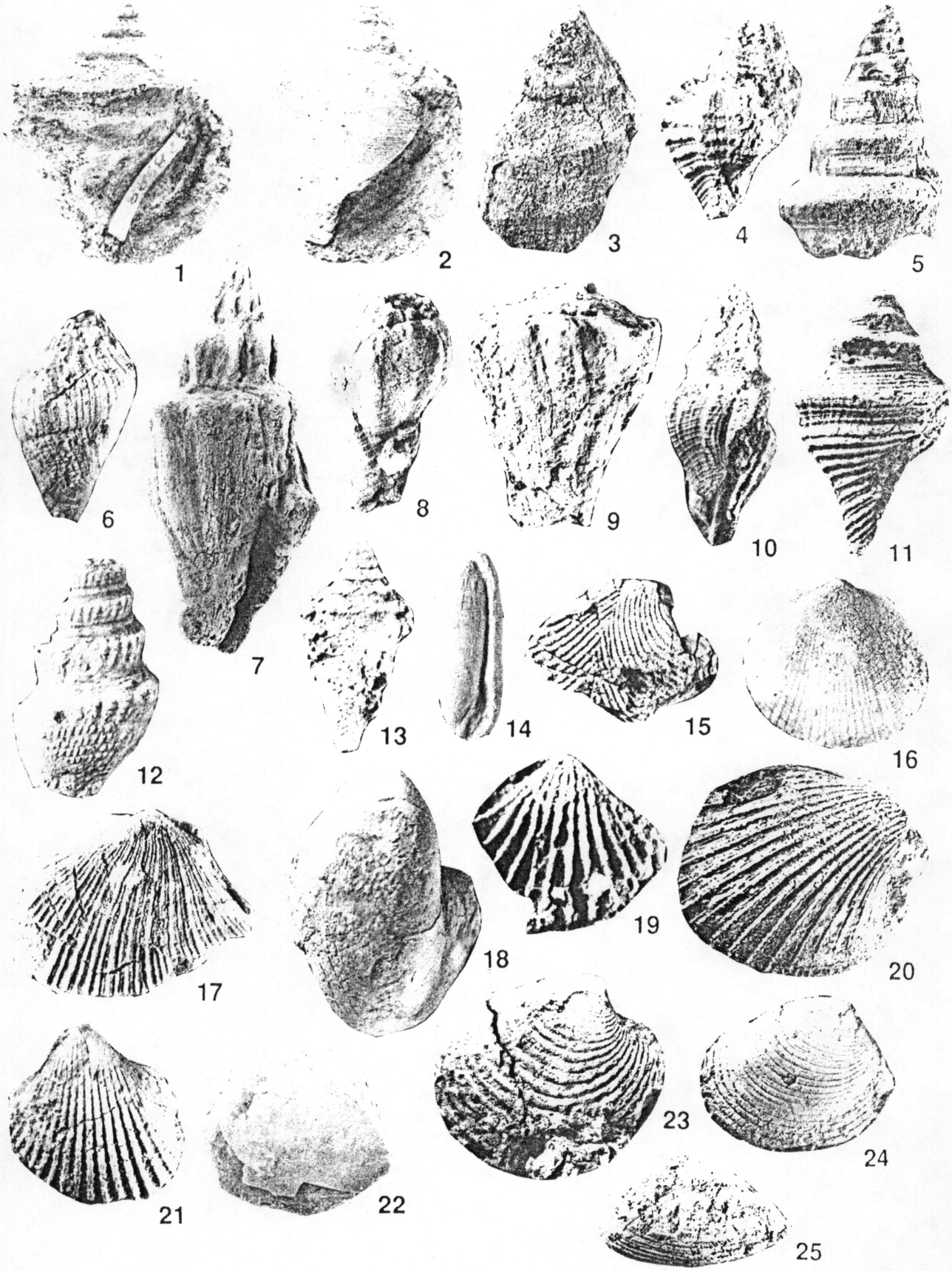
Plate 2

Figures 1-26. Maniobra Formation gastropods and bivalves identifiable as to species or subspecies. Figs. 1-15, gastropods. Figs. 16-26, bivalves.

1. *Galeodea* cf. *G. gallica* Wrigley, 1934, apertural view, x1.7, height 27.6 mm, width 24.7 mm, UCLA hypotype 28988, LACMIP loc. 23779 = CSUN loc. 662. LACMIP hypotype 8836
2. *Phalium* (*Semicassis*) *louella* Squires and Advocate, 1986, apertural view, x1.7, height 27.6 mm, width 22.3 mm, LACMIP holotype 7166, CSUN loc. 665.
3. *Ficopsis remondii crescentensis*?, partial specimen, abapertural view?, x2.3, height 20 mm, width 15 mm, LACMIP hypotype 11467.
4. *Favartia* ? sp., abapertural view, x4.9, height 7.5 mm, width 5 mm, LACMIP hypotype 11468.
5. *Clavilithes tabulatus* (Dickerson, 1913), spire only, x1.5, height 31 mm, width 20 mm, LACMIP hypotype 11469, CSUN loc. 662.
6. *Calorebama dilleri lineata* (Gabb, 1864), abapertural view, x5, height 7.5 mm, width 4.5 mm, LACMIP hypotype 11470, CSUN loc. 674.
7. *Volutilithes orocopiaensis* Squires and Advocate, 1986, apertural view, x1.2, height 62 mm, width 26.7 mm, LACMIP holotype 7168, CSUN loc. 662.
8. *Lyria andersoni* Waring, 1917, partial specimen, left side view, x1.7, height 23 mm, LACMIP hypotype 11471, CSUN loc. 675.
9. *Lyriscapha lajollaensis* (Hanna, 1927), left side view, x1.5, height 30 mm, LACMIP hypotype 11472, CSUN loc. 672.
10. *Pleurofusia fresnoensis* (Arnold, 1910), apertural view, x6, height 8 mm, width 3 mm, LACMIP hypotype 11473, CSUN loc. 662.
11. *Surculites mathewsonii* (Gabb, 1864), abapertural view, x1.7, height 30 mm, width 17 mm, LACMIP hypotype 11474, CSUN loc. 671.
12. *Domenginella* aff. *D. claytonensis* (Gabb, 1864), abapertural view, x4.5, height 9.5 mm, width 6 mm, LACMIP hypotype 11475, LACMIP loc. 23779 = CSUN loc. 662.
13. *Conus hornii umpquaensis* Turner, 1938, abapertural view, x6.5, height 6 mm, width 3 mm, LACMIP hypotype 11476, CSUN loc. 674.
14. *Cylichnina tantilla* (Anderson and Hanna, 1925), apertural view, x4, height 8.5 mm, width 3 mm, LACMIP hypotype 11477, LACMIP loc. 23779 = CSUN loc. 662.
15. *Acila* (*Trunacila*) *decisa* (Conrad, 1855), left valve, x5, length 7 mm, height 5 mm, LACMIP hypotype 11479, CSUN loc. 674.
16. *Glycymeris* (*Glycymerita*) *sagittata*? (Gabb, 1864), right? valve of a closed-valve specimen, , x3, length 11mm, height 10 mm, LACMIP hypotype 11480, LACMIP loc. 23779 = CSUN loc. 662.
17. *Spondylus* cf. *S. carlosensis* Anderson, 1905, partial specimen, left valve, x3.8, length 11 mm, height 9 mm, LACMIP hypotype 11481, LACMIP loc. 23779 = CSUN loc. 662.
18. *Ostrea haleyi* Hertlein, 1933, left valve, x1.5, length 23 mm, height 38 mm, LACMIP hyootype 11482, LACMIP loc. 23779 = CSUN loc. 662.
19. *Glyptoactis* (*Claibornicardia*) *domenginica* (Vokes, 1939), left valve, x9, length 4 mm, height 4 mm, LACMIP hypotype 11483, CSUN loc. 674.
20. *Glyptoactis* n. sp.?, x2.5, right valve of a closed-valve specimen, length 17 mm, height 13 mm, LACMIP hypotype 11484, CSUN loc. 662.
21. *Acanthocardia* (*Schedocardia*) *brewerii* (Gabb, 1864), left valve, x2.3, length 14 mm, height 10 mm, LACMIP hypotype 11485, CSUN loc. 671.
22. *Glossus* (*Meiocardia*) *susukii* Squires and Advocate, 1986, left valve, x2, length 16.5 mm, height 16 mm, UCLA holotype 48427, LACMIP loc. 23779 = CSUN loc. 662. LACMIP holotype 10568.
23. *Callista* (*Costacallista*) *hornii vokesi* Squires, 1987, left valve, x2.1, length 20 mm, height 18 mm, LACMIP hypotype 11486, CSUN loc. 675.
24. *Pitar* (*Lamelliconcha*) *joaquinensis* Vokes, 1939, right valve, x2.2, length 16 mm, height 14 mm, LACMIP hypotype 11487, CSUN loc. 674.
25. *Corbula* (*Caryocorbula*) cf. *C.* (*C.*) *dickersoni* Weaver and Palmer, 1922, left valve, x3.2, length 11 mm, height 7 mm, LACMIP hypotype 11488, CSUN loc. 676.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were collected from the Maniobra Formation. Forty-eight of these could be identified as to species or subspecies. These are one colonial coral, one solitary coral, one brachiopod, one polychaete worm, one scaphopod, 32 gastropods, and 11 bivalves, and they are listed in Table 1 and illustrated in Pls. 1 and 2. Two other bivalves, *Crassatella* sp. indet. and *Venericardia* (*Pacificor*) sp. indet. were too poorly preserved to allow specific identification but were listed in Table 1. Seventeen other taxa were too poorly preserved for generic identification and include clusters of polychaete worm? tubes, two epitoniid? gastropods, a calyptraeid? gastropod, two ranellid? gastropods, an olivid? gastropod, a turrid gastropod (possibly *Apiotoma*), one arcid bivalve, two ostreid bivalves, a fimbrid? bivalve, a pitarid bivalve, teredinid bivalve tubes, a crab, a spatangoid? echinoid, and a shark tooth.

The identifications of all the species listed by Crowell and Susuki (1959, p. 588-589) have been changed during the course of this study. These changes are shown in Table 2. Their specimens of *Ectinochilus* sp. cf. *E. macilentus*, *Keilostoma* sp. cf. *K. californicum* , and *Macrocallista* sp. were examined and found to be too poorly preserved to make generic identifications.

THIS REPORT	CROWELL & SUSUKI (1959)
Gastropods	
Amaurellina caleocia	*Amaurellina* sp.
Bittium cf. *B. preussi*	*B.* sp. cf. *B. longissimum*
Calyptraea diegoana	*Calyptraea* sp.
Chedevillia saltonensis	*C.* sp. cf. *C. stewarti*
Clavilithes tabulatus	*C.* sp. cf. *C. tabulatus*
Cylichnina tantilla	*Cylichnina*? sp.
Ectinochilus (*Vaderos*) *elongata*	*E.* n. sp.
Galeodea cf. *G. gallica*	*G.* sp. cf. *G. sutterensis*
Homalopoma aff. *H. wattsi*	*Homalopoma* sp. cf. *H. wattsi*
Lyria andersoni	*Lyria* sp.
Turritella andersoni	*T. andersoni lawsoni*
Turritella buwaldana	*T.* sp. cf. *T. buwaldana*
Turritella buwaldana	*Turritella buwaldana* n. var.
Turritella uvasana hendoni s.l.	*T. uvasana* n. var.
Bivalve	
Acanthocardia (*Schedocardia*) *brewerii*	*S.* cf. *S. brewerii*

Table 2. Equivalency of taxa identified in this report versus those listed in Crowell and Susuki (1959, p. 588-589).

Two new species may be present in the Maniobra Formation fauna. Two specimens of the polychaete worm *Rotularia* n. sp.? have a bicostate keel and are unlike any other Eocene *Rotularia* from the Paficic coast of North America. More specimens are needed of the polychaete worm in order to prove that they may represent a new species. Many juvenile specimens of the bivalve *Glyptoactis* n. sp.? have tripartite ribbing over the entire shell rather than just on the anterior part of each valve as in other *Glyptoactis* from the Paleogene of North America. Adult specimens are needed of the bivalve *Glyptoactis* n. sp.? in order to prove that it is a new species.

A single juvenile specimen of a muricid gastropod was found in the Maniobra Formation and is tentatively identified as *Favartia*. If this identification is correct, then this specimen is the first occurrence of genus *Favartia* in the Paleogene of the Pacific coast of North America.

GEOLOGIC AGE

Advocate et al. (1988) reported that the Maniobra Formation is early Eocene in age based on mollusks, calcareous nannofossils, and planktonic foraminifera. The molluscan taxa in the Maniobra Formation indicate the Pacific coast of North America provincial molluscan middle lower Eocene "Capay Stage," used in the restricted sense of Givens (1974). Taxa restricted to the "Capay Stage" were reported by Advocate et al. (1988) from the lower and middle parts of the formation. These taxa are *Turritella meganosensis protumescens*, *Turritella andersoni*, and *Ostrea haleyi*. Calcareous nannofossils indicative of CP9 to CP11 Zones (early Eocene) of Okada and Bukry (1980) and planktonic foraminifera indicative of P7 to P9 Zones (early Eocene) of Berggren et al. (1985) were reported by Advocate et al. (1988). No age-diagnostic fossils have been found in the upper 200 to 300 m of the Maniobra Formation.

The conclusion of Advocate et al. (1988) regarding the age of the Maniobra Formation using mollusks is confirmed in this present study. In addition, since their work was completed, an additional age-diagnostic molluscan species was found by the author in the submarine-canyon-fill deposits of the formation. *Turritella andersoni*, an index fossil of the "Capay Stage" (Squires, 1988) was found at numerous localities in the interval between 450 and 1,200 m above the base of the formation (Table 1; Fig. 2). It should be mentioned, however, that a few of the specimens of *T. andersoni* from the uppermost part of the formation do approach in morphology the upper lower to lower middle Eocene "Domengine Stage" *T. andersoni lawsoni*.

The presence of the bivalve *Spondylus* cf. *S. carlosensis* tentatively extends the geologic range of this species. Previously, it was confined to the "Domengine Stage" (Squires, 1987).

The bivalve *Glossus* (*Meiocardia*) *susukii* is the earliest reported species of *Meiocardia* on the Pacific coast of North and South America, and *Phalium* (*Semicassis*) *louella* is the earliest record of this genus/subgenus in North America (Squires and Advocate, 1986).

CORRELATION

As shown in Squires (1987, fig. 5; 1988, fig. 3) and Advocate et al. (1988), the Maniobra Formation is time correlative to the following "Capay Stage" (middle lower Eocene) strata on the Pacific coast of North America: Crescent Formation (in part), northwestern Washington (Snavely, 1987); Lookingglass Formation, southwestern Oregon (Heller and Dickinson, 1985); Capay Formation, Sacramento basin, northern California (Cherven, 1983); upper Lodo Formation, central California (Poore, 1976); Uvas Conglomerate Member of the Tejon Formation, San Emigdio Mountains, south-central California (Nilsen, 1987); Juncal Formation?, Lockwood Valley area, southern California (Squires, 1988); lowermost part of the Juncal Formation, Santa Ynez Range, southern California (Thompson, 1988); lower part of the Juncal Formation, Pine Mountain and Whitaker Peak areas, southern California (Givens, 1974; Squires, 1987); and lowermost marine part of the Llajas Formation, Simi Valley, southern California (Squires, 1984). In addition, recent work indicates that the Maniobra Formation is also time correlative to a part of the Bateque Formation, Baja California Sur, Mexico (Squires and Demetrion, in press), and to a part of the Tepetate Formation, Baja California Sur, Mexico (Squires and Demetrion, in review).

Kirkpatrick (1958) hypothesized that 310 km of post-Eocene right slip on the San Andreas fault has separated the Maniobra Formation from similar-appearing Eocene rocks in the Lockwood Valley area (Fig. 1). Howell (1975a, b) hypothesized that a more compelling match would be Eocene rocks in the Whitaker Peak-Pine Mountain area (Fig. 1) and that about 260 km of right slip on the San Andreas fault system has separated these two areas. Many authors have iterated these hypotheses, and these authors are listed in Advocate et al. (1988).

A thorough discussion of the validity of the postulations of Kirkpatrick (1958) and Howell (1975a, b) is beyond the scope of this present report. It is important to note, however, that detailed lithostratigraphic, biostratigraphic, and depositional environment

studies of the Lockwood Valley area (Squires, 1988) and the easternmost Whitaker Peak area (Squires, 1987; Yamashiro, 1989) are now available for comparison with the Maniobra Formation. Although the Maniobra Formation is time correlative with the Eocene rocks in the Lockwood Valley area and some of the Eocene rocks in the Whitaker Peak area, the Maniobra Formation does not match the lithologies, the overall macrofossil taxonomic composition, or the depositional environments of these lower Eocene rocks. In addition, the Maniobra Formation is overlain by different formations than those found in the other two areas.

BIOGEOGRAPHY

The early Eocene was a time of widespread tropical to subtropical conditions and coincided with the peak warming interval of the Cenozoic. The early through middle Eocene was also a time of influx of many Old World mollusks and other invertebrates into the Pacific coast region of North America by way of Central America (Squires, 1984; Squires, 1987). The archeogastropod *Velates perversus* is a cosmopolitan species (Squires, 1987). The gastropod *Galeodea gallica* is an Anglo-Paris Basin species (Squires and Advocate, 1986).

Some of the Maniobra Formation mollusks show Old World affinities. These are the gastropods *Campanile dilloni, Chedevillia saltonensis, Eocypraea? maniobraensis, Clavilithes tabulatus, Lyriscapha lajollaensis,* and *Volutilithes orocopianensis.*

Many of the Maniobra Formation macrofossil species are ones that also are present in other early Eocene faunas from the Pacific coast of North America. The colonial coral *Astrocoenia dilloni*, the gastropods *Velates perversus, Turritella andersoni, T. buwaldana, Campanile dilloni, Calyptogena diegoana, Eocernina hannibali, Pachycrommium clarki, Amaurellina caleocia, Clavilithes tabulatus, Lyria andersoni, Lyriscapha lajollaensis, Pleurofusia fresnoensis, Surculites mathewsonii, Cylichnina tantilla,* and the bivalves *Acila (Truncacila) decisa, Ostrea haleyi, Glyptoactis (Claibornicardia) domenginica, Acanthocardia (Schedocardia) brewerii,* and *Pitar (Lamelliconcha) joaquinensis* are all species that are widespread in lower Eocene strata of the Pacific coast of North America (Squires, 1984, 1987, 1988; Squires and Demetrion, in press).

The presence of the brachiopod *Kingena? simiensis* in the Maniobra Formation extends the geographic range of this species. Previously, it was only known from Simi Valley, southern California (Hertlein and Grant, 1944). The presence of the gastropod *Ectinochilus (Vaderos)* cf. *E. (V.) elongata* tentatively extends the geographic range of this species. Previously, it was only known from the Cowlitz Formation of southwestern Washington (Weaver, 1943).

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LOCALITIES

All are CSUN localities and, unless otherwise noted, are in the United States Geological Survey Red Canyon, provisional edition, 1986, 7.5-minute topographic quadrangle, Riverside County, southern California.

662. 2,910 ft elevation along crest of small hill, 137 m (450 ft) south and 31 m (100 ft) west of the northeast corner of sec. 25, T6S, R12E, Hayfield, provisional edition, 1987, 7.5-minute topographic quadrangle, Riverside County, southern California. This locality is the same as locality F of Crowell and Susuki (1959) = LACMIP loc. 23779 = UCLA loc. 3779.

665. 2,120 ft elevation along east side of small canyon, 861 m (2,825 ft) north and 709 m (2,325 ft) west of the southeast corner of sec. 30, T6S, R13E. = LACMIP locality 16335.

667. 2,040 ft elevation along east side of canyon, 183 m (600 ft) south and 213 m (700 ft) west of the northeast corner of sec. 31, T6S, R13E.

668. 2,000 ft elevation in stream bed, 421 m (1,380 ft) south and 198 m (650 ft) east of the northwest corner of sec. 31, T6S, R13E. = LACMIP loc. 16155.

669. 2,120 ft elevation along south side of stream, 152 m (500 ft) south and 198 m (650 ft) west of the northeast corner of sec. 36, T6S, R12E. = LACMIP loc. 16894

670. 2,180 ft elevation at southeast end of butte, 274 m (900 ft) north and 808 m (2,650 ft) east of southwest corner of section 25, T6S, R12E.

671. 2,040 ft elevation in stream bed, 579 m (1,900 ft) north and 26 m (85 ft) west of the southeast corner of sec. 31, T6S, R13E. = LACMIP locality 16076

672. 1,840 ft elevation in stream bed, 366 m (1,200 ft) north and 76 m (250 ft) west of the southeast corner of sec. 31, T6S, R13E. = LACMIP locality 16274.

673. 1,960 ft elevation in stream bed, 670 m (2,200 ft) north and 381 m (1,250 ft) west of the southeast corner of sec. 36, T6S, R12E.

674. 1,940 ft elevation along east side of stream bed, 579 m (1,900 ft) south and 472 m (1,550 ft) west of southeast corner of sec. 6, T7S, R13E. = LACMIP locality 16082

675. 2,000 ft elevation along crest of small ridge, 594 m (1,950 ft) north and 701 m (2,300 ft) west of southeast corner of sec. 36, T6S, R12E. = LACMIP locality 16151.

676. 2,010 ft elevation along north side of stream bed, 671 m (2,200 ft) north and 786 m (2,580 ft) west of southeast corner of sec. 36, T6S, R12E. = LACMIP locality 16192

677. 2,060 ft elevation, 411 m (1,350 ft) south and 518 m (1,700 ft) east of northwest corner of sec. 6, T6S, R12E.

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