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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.

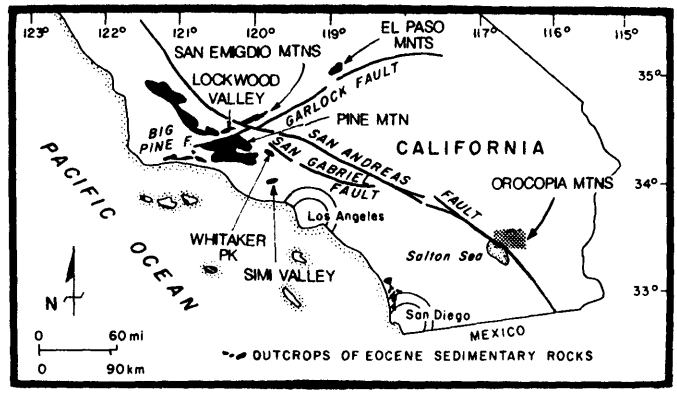

Figure 1. Index map of southern California showing major faults, Eocene outcrops, and study area. Modified from Advocate et al. (1988).

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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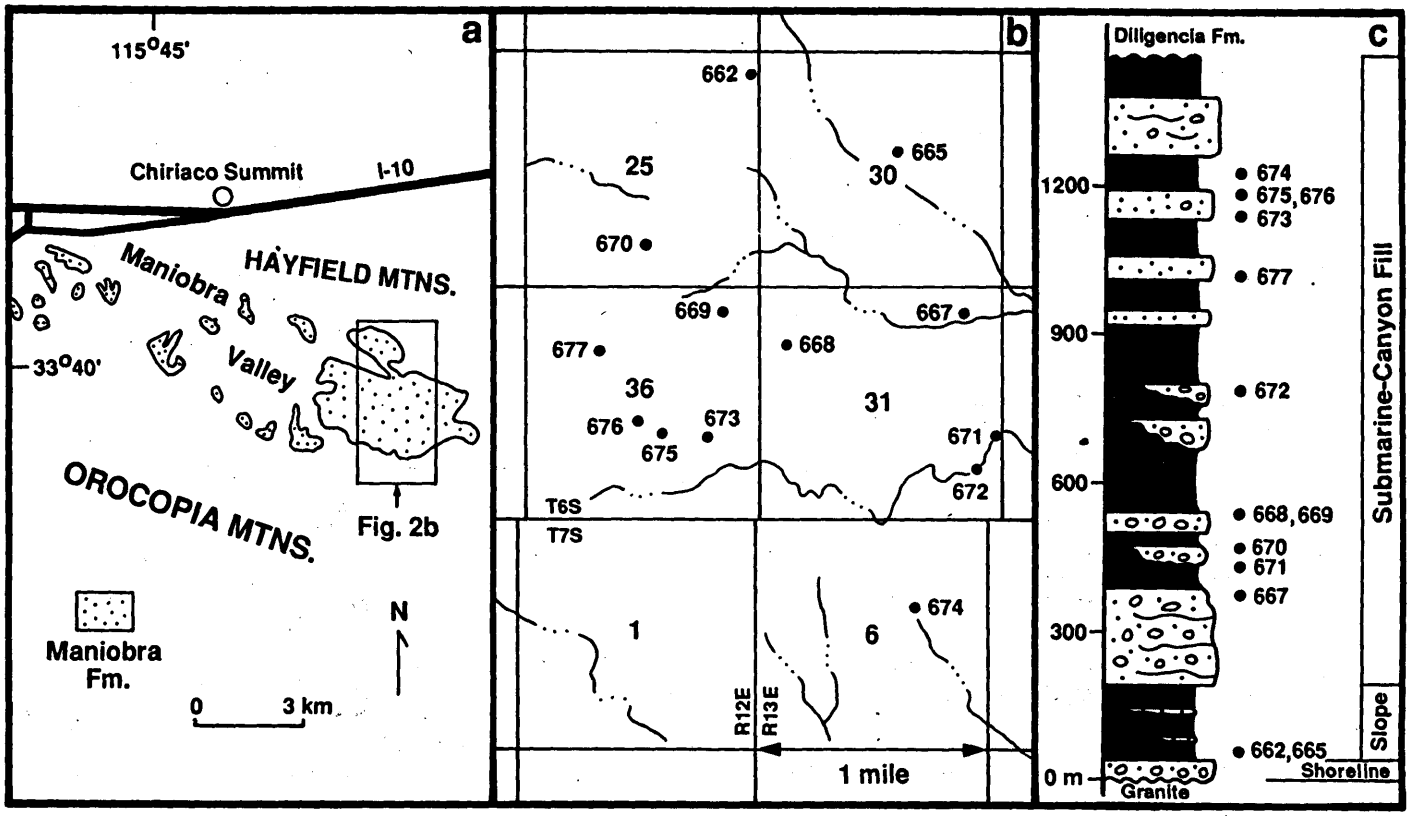

Figure 2. a) Index map showing outcrops of Maniobra Formation and area of enlargement shown in Fig. 2b; b) Location of CSUN macrofossil localities; c) Simplified and generalized stratigraphic column of the Maniobra Formation showing stratigraphic position of each macrofossil locality.

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.