

Paleocene pareorine turritellid gastropods from the Pacific slope of North America

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ABSTRACT

This paper presents the first detailed study of *Mesalia martinensis* (Gabb, 1869) and *Mesalia clarki* (Dickerson, 1914a), the only two known pareorine (spout-bearing) turritellid gastropods from the Pacific slope of North America. Both species are redescribed, in light of new morphologic information that also confirms their assignment to genus *Mesalia* Gray, 1847, which we believe to be congeneric with *Sigmesalia* Finlay and Marwick, 1937. New stratigraphic information allows for refinement of the chronologic range of each species. *Mesalia martinensis* is of early late Paleocene (late Danian) to early late Paleocene (early Thanetian) age and ranges from northern California to northern Baja California. *Mesalia clarki* is of late middle to early late Paleocene age (late Selandian to early Thanetian) age and is known only from California; in southern California it is restricted to a coralline-algal facies. Both species have considerable variability in their spiral sculpture.

Mesalia originated during either the Late Cretaceous (Maastrichtian) in northern Africa or the early Paleocene (Danian) in northern Africa and western Iran. It became widespread during the warm (greenhouse) conditions of the Paleocene and Eocene but became geographically restricted during subsequent cooler global conditions. *Mesalia* is an extant genus with possibly six species, and whose total geographic range is in coastal waters in southern Portugal, southern Spain, Mediterranean Sea (primarily the western part), Canary Islands, and the west coast of northern Africa.

INTRODUCTION

The object of this study was to rectify the identification uncertainties concerning the only two known pareorine (spout-bearing) turritellid gastropod species from shallow-marine rocks on the Pacific slope of North America. They are *Mesalia martinensis* (Gabb, 1869) and *Mesalia clarki* (Dickerson, 1914a). Most modern workers

(e.g., Zinsmeister, 1983) have generally placed both species in *Mesalia* Gray, 1847, but some workers (e.g., Saul, 1983a: fig. 2; Squires, 2003: table 2.4) have been hesitant to unequivocally use the genus name because of inadequate morphologic information about these species. The shape of the aperture of the latter one was unknown until now, and apertural information is critical in distinguishing pareorine gastropods from similar looking turritellids (see “Systematic Paleontology” for morphological comparisons). There has also been the possibility that *Mesalia macreadyi* Waring, 1914, which has commonly been put into synonymy with *M. martinensis*, could be a distinct species.

We conclude that there are only two species, both belonging to *Mesalia*, which we believe to be congeneric with *Sigmesalia* Finlay and Marwick, 1937. In addition to providing new morphologic information about the study area *Mesalia*, we refine their geographical (Figure 1) and chronologic ranges (Figure 2). Both *M. martinensis* and *M. clarki* have considerable variability in their spiral sculpture.

Mesalia has long been reported (e.g., Cossmann, 1912) as originating during the Late Cretaceous in the region between northern Africa and western Iran. Our review of the literature shows that the genus most likely originated during either the Late Cretaceous (Maastrichtian) or the early Paleocene (Danian) in this Old World region.

Modern systematic studies of *Mesalia* are sorely lacking as are detailed ecologic studies of the few extant species. The classification scheme used here follows that of Bouchet et al. (2005: 249), and morphological terms are taken from Cox (1960). Pacific slope of North America *Turritella* zones are taken from Saul (1983b).

Institutional abbreviations used in the text are: ANSP: Academy of Natural Sciences of Philadelphia; LACM: Natural History Museum of Los Angeles County, Malacology Section; LACMIP: Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; UCMP: University of California, Berkeley, Museum of Paleontology.

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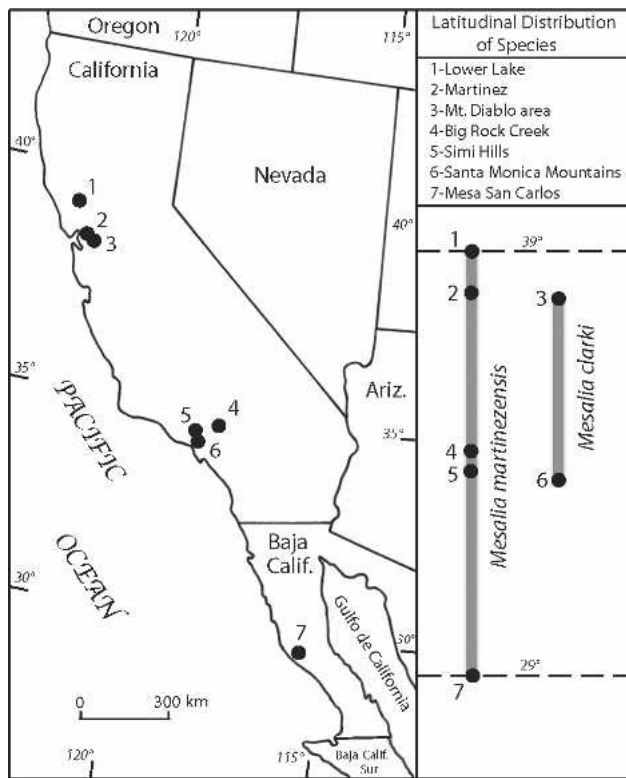


Figure 1. Locales and latitudinal distribution of the study area gastropods.

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

The geologic ages of the formations and most of the depositional environments of the formations containing the two studied species are mentioned in Squires (1997).

Mesalia martinzeensis is widespread in the study area (Figure 1) and always found in siltstone or sandstone beds that formed either as storm accumulations of mollusk-rich assemblages in shelfal-marine depths or as localized displaced shallow-marine mollusks in deeper

Age (Ma)	System/Series	European Stages	<i>Mesalia martinzeensis</i>	<i>Mesalia clarki</i>	<i>Turritella</i> Zones
55	Lower Paleocene	Ypresian			
		Upper Thanetian			<i>T. infragranulata</i>
60	Middle Paleocene	Selandian			<i>T. l. pachecoensis</i>
		Danian			<i>T. peninsularis</i> <i>T. peninsularis qualeyi</i>
65	Lower Paleocene				
	Upper Cret.	Maastr.			

Figure 2. Chronostratigraphic position of the study area taxa. Ages of stage boundaries from Gradstein et al. (2004). *Turritella* zones from Saul (1983b).

depths. These mollusks commonly include shallow-marine mollusks such as naticid and buccinid gastropods, as well as glycymerid and crassatellid bivalves. All are indicative of normal marine salinities.

The type locality of *Mesalia martinzeensis* has been generally assigned (e.g., Keen and Bentson, 1944) to the “Martinez Formation” in the vicinity of the city of Martinez, Contra Costa County, northern California (Figure 1). The history of how early workers referred to this originally poorly defined “formation” has been summarized by Mallory (1959). In this present study, we follow the work of Weaver (1953), who refined the stratigraphy of the Paleocene and Eocene formations in the vicinity of the area where the “Martinez group” was first established. He established new stratigraphic names, and the rocks that pertain to the type locality of *M. martinzeensis* belong in his Paleocene Vine Hill Sandstone.

Mesalia clarki is only known from two locales: 1) its type locality (UCMP loc. 1540, see “Appendix”) on the north flank of Mount Diablo, Contra Costa County, northern California, and 2) from the Santa Monica Mountains, Los Angeles County, southern California (Figure 1). Its type locality is near the site of Stewartville, and approximately 24 km east-southeast of the city of Martinez, and, according to Dickerson (1914a: 74), this locality is “300 to 400 ft. above the base of the Martinez in hard, gray-green glauconitic sandstone.” Numerous mollusks have been found at this locality (Dickerson, 1914a: 75). They consist of turritellid and buccinid gastropods, crassatellid bivalves, and other shallow-marine species, all indicative of normal marine salinities. *Turritella infragranulata pachecoensis* Stanton, 1896, which is found at this locality, is indicative of the upper middle Paleocene (upper Selandian) (Figure 2). On the geologic map of Brabb et al. (1971), the locality plots within the glauconitic sandstone lower member of the “Martinez” Formation. Megafossils are generally scarce in the “Martinez” Formation in the vicinity of this type locality (E. Brabb, personal commun.), thus, it seems plausible that the fossils probably occur in storm-derived, isolated lenses.

Mesalia clarki in the Santa Susana Formation in the Palisades Highlands area of the Santa Monica Mountains, southern California, is always found near outcrops of coralline-algal limestone. Hoots (1931: 91–92, 133–134, pl. 19B) reported that these limestones are resistant, can be cliff forming, weather white, are nodular and irregularly bedded, up to 35 m thick, up to 1200 m in lateral extent, and commonly terminate in an abrupt wall. Additional geologic and/or paleontologic details concerning these limestones are mentioned in Strathearn et al. (1988), Colburn (1996), Squires and Saul (1998), Squires and Kennedy (1998), and Squires and Saul (2001).

At LACMIP loc. 10508, in the Palisades Highlands area, abundant specimens of *M. clarki* are found in a thin coralline-algal-rich micaceous muddy siltstone bed about 1 m stratigraphically below a blocky, coralline-algal-limestone interval approximately 24 m thick. Also found

in this bed is the large neritid gastropod *Corsania (Januncia) rhoga* Saul and Squires, 1997, as well as the bivalves *Plicatula lapidicina* Squires and Saul, 1998, and *Plicatula trailerensis* Squires and Saul, 1998. Occurring in nearby beds in close association with the coralline-algal deposits are the gastropods *Terebralia susana* Squires and Kennedy, 1998, and *Campanile greenellum* Hanna and Hertlein, 1939. All of these aforementioned mollusks indicate very nearshore, tropical to subtropical conditions (Squires and Saul, 1997; Squires and Kennedy, 1998). The latter workers concluded that the coralline-algal limestones, like those at locality 10508, were deposited in a protected bay (no deeper than 40 to 70 m) with warm-algal-limestone buildups associated with shoals on the bay floor. These limestone buildups are very similar in lithology and sedimentologic/tectonic setting to limestones in the Paleocene Sepultura and Bahia Ballenas formations in northern Baja California (Abbott et al., 1995), as well as similar to limestones in the upper Paleocene to lower middle Eocene Sierra Blanca Limestone in Santa Barbara County, southern California. These limestones were deposited when tectonic plate-edge strain in the fore-arc basin caused local basement highs to form within the otherwise deeper marine environment (Whidden et al., 1995; Abbott et al., 1995). It is likely that the Santa Susana Formation coralline-algal limestones formed under similar conditions.

Although *Mesalia clarki* and *Mesalia martinezensis* both occur in the Santa Susana Formation in the Santa Monica Mountains, southern California, they never occur together in the same beds. *Mesalia martinezensis* is not associated with the coralline-algal facies there or anywhere else in the study area.

PALEOBIOGEOGRAPHIC IMPLICATIONS

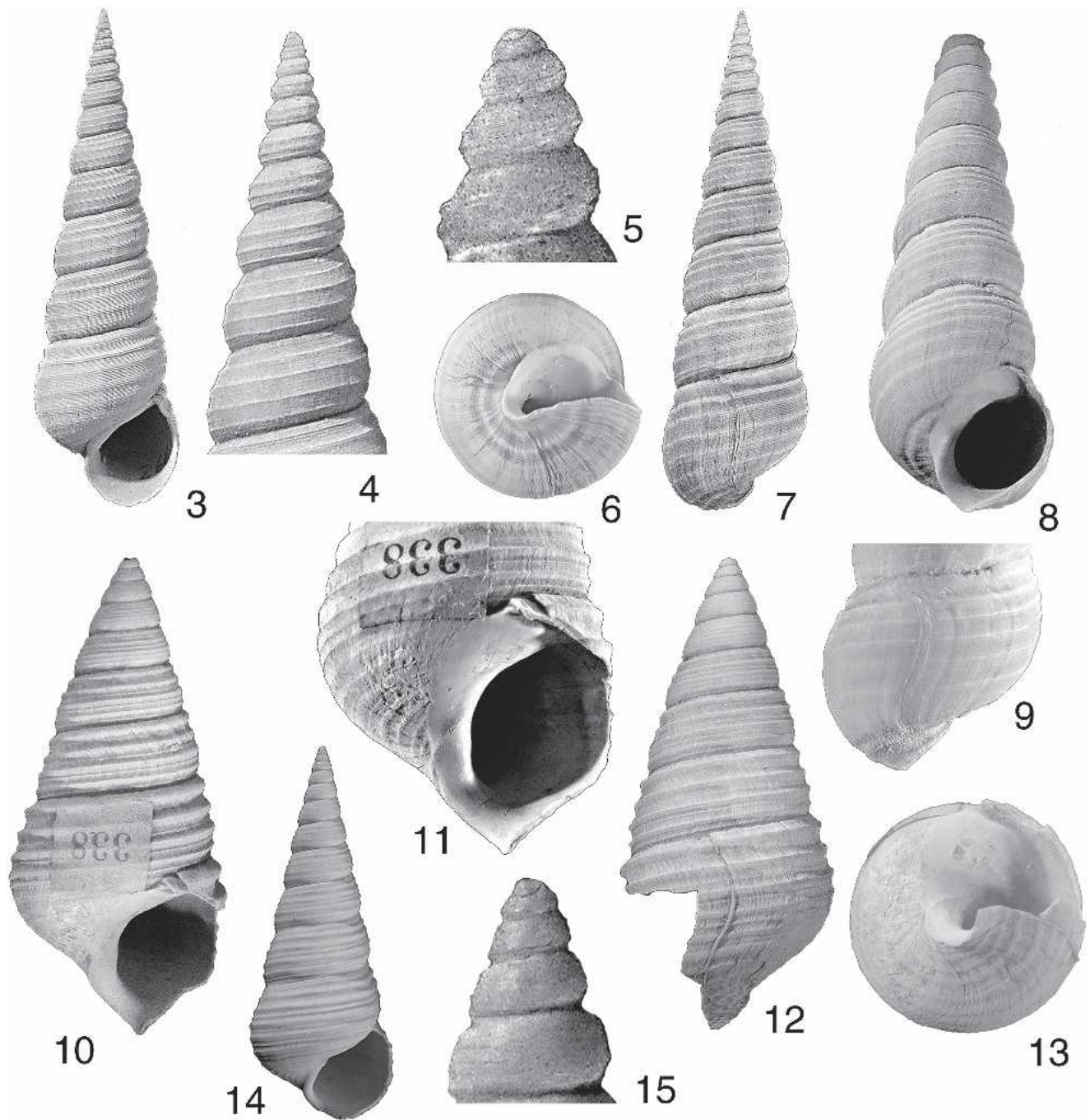
Kiel and Bandel (2004: 120, fig. 7I) reported two specimens of *Mesalia* cf. *multilineata* (J. Müller, 1851) from Cenomanian strata at the Kassenberg quarry in Germany. If these specimens actually belong to *Mesalia*, they would be the geologically oldest. The conical-turriculate shell with convex whorls bearing strong spiral ribs does resemble *Mesalia*, but there are no specimens with an intact aperture nor with a protoconch. *Turritella multilineata* J. Müller (1851: 29, pl. 4, figs. 4, 6) was originally reported from the lower Campanian Aachen strata of Germany, thus, it is considerably younger than the Kassenberg quarry material. *Turritella multilineata* was also figured by G. Müller (1898: 97, pl. 13, figs. 4, 5), who reported it from middle Santonian to lower Campanian strata at Braunschweig/Ilse, Germany. There is also a mention of *T. multilineata* in Kollmann and Odin (2001: 441), and they also consider this Campanian species to belong to genus *Turritella*. The pleural angle of J. Müller's figure is much narrower than that of Kiel and Bandel (2004), and in our opinion, Kiel and Bandel's *M.* cf. *M. multilineata* (J. Müller) does not look like J. Müller's species. Kiel and Bandel (2004) tentatively syn-

onymized J. Müller's specimens and G. Müller's specimens with their Kassenberg quarry specimens. We believe, however, that Kiel and Bandel's Cenomanian specimens have nothing to do with *T. multilineata* and represent, at best, a very questionable *Mesalia*. More specimens of this possible *Mesalia* from the Cenomanian of Germany are needed in order to determine its generic assignment.

Cossmann (1912: 126) reported the chronologic range of *Mesalia* to be Late Cretaceous (Turonian) to Recent, as did Wenz (1939), who apparently simply reiterated Cossmann's findings. We were unable, however, to corroborate any of Cossmann's Cretaceous occurrences. He reported *Mesalia gazellensis* Whitfield (1891: 424, pl. 9, fig. 10) as being from the Turonian of Syria, but the aperture of this species is unknown. In addition, the sculpture is obsolete, which is unlike *Mesalia*.

Cossmann (1912: 126) listed five *Mesalia* species of Late Cretaceous (Senonian) age, and these are discussed in the following sentences. *Arcotia indica* Stoliczka (1868: 215, 469, pl. 16, figs. 12, 12a; pl. 19, fig. 6) from southern India is not a *Mesalia*. This species is also discussed later under "Systematic Paleontology." Specimens of *Turritella ventricosa* Forbes (1846: 123, pl. 13, fig. 3; Stoliczka, 1868: 227, pl. 17, fig. 15) from southern India are missing the aperture. *Turritella martinezensis* Gabb (1869: 159, pl. 28, fig. 51) from California is not of Cretaceous age. *Mesalia nettoana* White (1887: 164–165, p. 18, figs. 3, 4) from the Maria Farinha beds in Brazil is Paleocene age. *Mesalia hebe* White (1887: 165, pl. 18, fig. 5), also from Brazil, looks like a juvenile specimen of *M. nettoana*.

Cossmann (1912: 126) also listed two Late Cretaceous (Maastrichtian) species. The first one is *Mesalia jovisammonis* (Quaas, 1902: 256, pl. 26, figs. 18–20), which Quaas reported, in a very generalized way, to be associated with the *Exogyra overwegi* biozone at Ammonite Hill in the Great Sand Sea in western Egypt. This biozone can also be recognized in the Maastrichtian (but not latest Maastrichtian) part of the Ammonite Hill Member of the Campanian to Paleocene Dakhla Formation in western Egypt (Barthel and Herrmann-Degen, 1981). Tantawy et al. (2001) assigned this member an early to early late Maastrichtian age, based on planktic foraminifera, calcareous nannofossils, and macrofossils. They also determined, however, that the entire formation ranges in age from early Maastrichtian to early Danian. Immediately above the widespread K/T disconformity in the region, a sedimentologically complex sequence marks the lower Danian Bir Abu Minquar horizon, which contains a mixture of Maastrichtian (reworked) and Danian fossils, including both microfossil and macrofossil species (e.g., including some ammonites.). Unfortunately, Quaas did not provide any information as to where exactly in the stratigraphic section he collected the specimens of *M. jovisammonis*. His specimens were lost, so it is not possible to match their rock matrix to actual outcrops. Recollecting of this gastropod is necessary to decipher its exact geologic age.



Figures 3–15. Type species of *Mesalia* and *Sigmesalia*, plus comparative pictures of *Mesalia solida* (Deshayes, 1861). Specimens coated with ammonium chloride. **3–9.** *Mesalia mesal* (Adanson, 1757), Baie de Hann, Senegal, West Africa (Recent). **3–7.** Hypotype LACM 173163. **3.** Apertural view, height 45 mm, diameter 15 mm. **4.** Tip of specimen shown in previous figure, height 14 mm, diameter 5.5 mm. **5.** Protoconch and earliest spire whorls, apertural/ right-lateral view, height 1 mm, diameter 0.7 mm. **6.** Base, diameter 15.6 mm. **7.** Abapertural view, height 45 mm, diameter 15 mm. **8–9.** Hypotype LACM 173164. **8.** Oblique apertural view, height 51 mm, diameter 16.3 mm. **9.** Close-up of abapertural view of last whorl, diameter 17.2 mm. **10–13.** *Mesalia koeneni* (Le Renard, 1994), LACMIP hypotype 13397, Grignon, Paris Basin, France (middle Eocene, Lutetian Stage), height 45.8 mm, diameter 20.3 mm. **10.** Apertural view. **11.** Close-up of aperture. **12.** Right-lateral view (outer lip broken). **13.** Base. **14–15.** *Mesalia solida* (Deshayes, 1861), hypotype LACMIP 13398, Le Guépelle, Paris Basin, France (late Eocene). **14.** Apertural view, height 21.6 mm, diameter 8.1 mm. **15.** Protoconch and earliest spire whorls, apertural to slightly right-lateral view, height 1 mm, diameter 0.7 mm.

Abbass (1963: 39–40, pl. 2, figs. 20–22) illustrated *M. jovisammonis* from eastern Egypt and referred to it as *Mesalia* (*Woodsalia*) *jovisammonis* of Maastrichtian age. He did not provide, however, any discussion as to how this age was determined.

Mesalia cf. *M. multisulcata* (Lamarck 1804), reported by Serra (1937: 313–315, pl. 16, figs. 12, 12a, 13) from near Tripoli, Libya, looks like it might be conspecific with *Mesalia jovisammonis*. Serra provided no detailed stratigraphic or geologic age information.

The second species that Cossmann (1912) listed from the Maastrichtian is *Mesalia fasciata* (Lamarck, 1804) from Iran. Cossmann based this occurrence on work by Douvillé (1904: 329–330, pl. 47, figs. 23–27), who reported *M. fasciata* from the “Couches à Cérithes” beds in the Luristan region in west-central Iran. Douvillé (1904) believed that these Iranian specimens of *M. fasciata*, whose type locality is in middle Eocene (Lutetian Stage) strata at Grignon in Paris Basin, France (Eames, 1952: 34), are of Maastrichtian age, but the “Couches à Cérithes” beds contain the bivalve “*Cardita*” *beaumonti* d’Archiac and Haime, 1854, which is diagnostic of earliest Danian age in Iran and Pakistan (Douvillé, 1928; Eames, 1952; Davies, 1975). *Mesalia fasciata* is long-ranged geologically (early Paleocene to late Eocene) and widespread geographically (western Europe to Pakistan) (Eames, 1952).

Another *Mesalia* that needs investigation as to its precise stratigraphic position and geologic age is *Mesalia foucheri* Pervinquièrre (1912: 44, pl. 3, figs. 6–15), from the Ghadames (Garat Temblili) region in Tunisia, northern Africa. Pervinquièrre (1912: 336) reported the species as being of Maastrichtian age, but no critical geologic details are provided. He did differentiate between Maastrichtian and Danian fossils; thus, like in nearby Egypt and Libya, the stratigraphic section containing *M. foucheri* and other macrofossils in Tunisia, also spans the K/T boundary.

Two species of so-called *Woodsalia* Olsson, 1929, from Upper Cretaceous (Campanian?) strata in northwestern Peru (Olsson, 1944) might eventually be placed in *Mesalia*, once their apertures become known. They are: *Woodsalia paitana* Olsson (1944: 69–70, pl. 11, fig. 5) and *Woodsalia paitana robusta* Olsson (1944: 70, pl. 11, figs. 3, 9).

The so-called *Mesalia* (*Mesalia*) *mauryae* Allison (1955: 414–415, pl. 41, fig. 3; Perrilliat, 1989: 149, fig. 51h) from the upper Aptian upper member of the Alisitos Formation, Punta China region, Baja California, Mexico, is, according to Squires and Saul (2006), *Turritella seriatimgranulata* Roemer, 1849.

In addition to the above-mentioned Old World Danian species of *Mesalia*, three New World Danian species are known from the Gulf Coast of the southeastern United States. They are from the Clayton Formation (Palmer and Brann, 1966), which is of earliest Danian age (Dockery, 1986). The three species are: *Mesalia allentonensis* (Aldrich, 1894: 246–247, pl. 13, figs. 4a, 4b, 6; Stenzel

and Turner, 1942: card 110); *Mesalia hardemanensis* (Gabb, 1860: 392, pl. 68, fig. 15; Stenzel and Turner, 1942: card 116); and *Mesalia pumila* (Gabb, 1860: 392, pl. 68, fig. 14; Stenzel and Turner, 1942: card 118).

In summary, our search of the literature revealed that *Mesalia* most likely originated during either the Maastrichtian in northern Africa or the early Paleocene (Danian) in northern Africa and western Iran. During the Danian it spread quickly to the Gulf Coast of the United States by means of westward-flowing ocean currents emanating from the western Tethyan region. These currents, which existed during the Late Cretaceous (Gordon, 1973; Johnson, 1999) and continued into the Paleocene and Eocene (Saul, 1986; Squires, 1987), were part of a circumglobal-tropical current that contributed to a widespread dispersal of marine biota (Haq, 1981). By the late Danian, it reached California and northern Baja California, Mexico, as well as Belgium (Cox, 1930; Glibert, 1973). By middle Paleocene, it reached Greenland (Kollmann and Peel, 1983), and by the late Paleocene, it reached Nigeria (Adegoke, 1977). During the Paleocene and Eocene, *Mesalia* reached its peak diversity and became most widespread, with occurrences mainly in the Old World western Tethys Sea region. We did not detect, however, any reported occurrences in Australia, New Zealand, Japan, or Antarctica. The Paris Basin of France (see Cossmann and Pissarro, 1910–1913), southwestern Nigeria (Adegoke, 1977), and the Gulf Coast of the United States (Stenzel and Turner, 1940, 1942; Palmer and Brann, 1966) are the principal areas in which numerous species of *Mesalia* have been recognized. Some species became very widespread. For example, as mentioned earlier, *Mesalia fasciata* ranged from the Paris Basin, France to Pakistan (Eames, 1952). After the warm greenhouse conditions that existed during the Eocene, *Mesalia* was much reduced in its distribution and mainly occurred in what is now the Mediterranean Sea region (Cossmann, 1912).

MODERN MESALIA

Mesalia is extant and review of the scant literature, as well as use of the internet (note: <<http://www.alboranshells.com/turritellidae>> was particularly helpful), revealed as many as possibly six species. They are the following: *M. mesal* (Adanson, 1757), *M. breviaлис* Lamarck, 1822; *M. varia* Kiener, 1843; *M. opalina* Adams and Reeve, 1850; *M. freytagi* von Maltzan, 1884; and *M. flammifera* Locard, 1897, which includes the subspecies *M. flammifera flammifera* Locard, 1897 and *M. flammifera simplex* Locard, 1897. There is much confusion as to exactly how many species there are, and potential synonyms need to be resolved. For example, some workers (e.g., Smith, 1915; Bowles, 1939) equated *M. mesal* with *M. breviaлис*, but other workers (e.g., Advovini and Cosignani, 2004) separated them. Bowles (1939) gave a thorough review of the nomenclatural history of *Mesalia breviaлис*.

A comprehensive malacological study of the modern species of *Mesalia* is greatly needed. Because of the uncertainties stemming from the poorly known systematics, it is confusing to try to determine which species is found where. We were able to establish with certainty (see references below), however, that modern *Mesalia* is only found in the Atlantic coastal areas of southern Portugal, southwestern Spain, Morocco, Canary Islands, Western Sahara, Mauritania, Senegal, and Guinea, as well as in the westernmost Mediterranean Sea, particularly in the Alboran Sea (i.e., Strait of Gibraltar to southern Spain on the north and Morocco on the south) and the Aegean Sea region of western Turkey.

Mesalia mesal and *M. brevisalis* have the widest distribution. *Mesalia mesal* has been reported from the Algarve region of southern Portugal, the Algeciras region of southwestern Spain, and the Alboran Sea (Poppe and Goto, 1991), the Canary Islands (Macedo and Borges, 1999), Senegal (Bouchet, 1977; Ardovini and Cossignani, 2004), and western Turkey (Demir, 2003). *Mesalia brevisalis* has been reported from the Algarve region of southern Portugal (Afonso et al., 2000; Alves et al., 2003), southwestern Spain and the Alboran Sea (Hidalgo, 1917), Senegal (Ardovini and Cossignani, 2004), and Guinea (Pasteur-Humbert, 1962). *Mesalia opalina* has been reported from the Canary Islands and Morocco (Poppe and Goto, 1991), as well as from Mauritania (Ardovini and Cossignani, 2004). The other modern species/subspecies of *Mesalia* are apparently restricted to the northwestern coast of Africa (Ardovini and Cossignani, 2004).

Mesalia melanioides Reeve, 1849, was reported (Smith, 1915) to be from West Australia, but this species is now the type species of *Neodiastoma* Cotton, 1932, which differs from *Mesalia* by having axial sculpture on the early spire. Marwick (1957) summarized the systematics of *Neodiastoma* and classified it as a pareorine.

Mesalia is found today on both muddy and sandy bottoms in coastal waters ranging in depth from lower intertidal to 20 m (Hidalgo, 1917; Pasteur-Humbert, 1962; Poppe and Goto, 1991; Afonso et al., 2000; Demir, 2003; Alves et al., 2003). Bouchet (1977) reported that *M. mesal*, although not common there, can be found in the seaward part of mangrove-swamp systems along the coast of Senegal. Specimen LACM 17316 (Figures 3–7) of *M. mesal* was collected in approximately 5 m depth, on sand and rubble in Senegal.

Large numbers of *M. mesal* have been reported (Afonso et al., 2000) as almost always being partially infaunal (with their apices pointed upward) when found on exposed low-tide mud flats on the inner lagoon sides of islands within the Rio Formosa coastal-lagoon system of southern Portugal.

The modern ecological parameters mentioned above are not totally reliable for fossil *Mesalia* because preferences for substrate and depth of water might have possibly changed over time. In addition, the fossil occurrences of *Mesalia* had a pan-Tethyan distribution,

whereas the modern occurrences have contracted primarily to the Iberian Peninsula, Alboran Sea, and northwestern Africa.

SYSTEMATIC PALEONTOLOGY

Superfamily Cerithioidea Fleming, 1822

Family Turritellidae Lovén, 1847

Discussion: Allmon (1996: 9–12, table 1) thoroughly reviewed the history of the classification of turritellid gastropods and listed the five subfamilies and all the genera/subgenera within each subfamily. These subfamilies are: Turritellinae Löven, 1847; Protominae Marwick, 1957; Pareorinae Finlay and Marwick, 1937; Vermiculariinae Lamarck, 1799; and Turritellopsinae Marwick, 1957. Bouchet et al. (2005) included the first four of these subfamilies, but removed Turritellopsinae. Instead, they included subfamily Orectospirinae Habe, 1955.

Subfamily Pareorinae Finlay and Marwick, 1937

Discussion: Pareorine turritellids are characterized from the other subfamilies of family Turritellidae by having an aperture obliquely effuse over the anterior end of the columella and forming a sinus (short spout), with the adapical margin of the sinus usually making a spiral ridge on the columella (Marwick, 1957).

Mesalia can be readily identified if its aperture is intact, but when it is missing, workers have commonly misassigned it to the similar looking genus “*Turritella*” Lamarck, 1799, *sensu lato*, a group comprising at least 35 genera and subgenera names (Allmon, 1996), all of which are turritellines whose apertures do not have a sinus (short spout) at the anterior end of the aperture nor have a spiral ridge on the columella. In addition, according to Smith (1915), the corneous operculum of *Mesalia* is paucispiral and not multispiral, as in “*Turritella*,” but this later distinction is not useful when studying fossil species.

Ten pareorine genera were listed by Marwick (1957), who also provided illustrations of the growth-line traces of some of these genera. Comparative information about the stratigraphic range, growth-line details, whorl profile, and protoconch shape of most of these genera was given by Allmon (1996: table 1).

Genus *Mesalia* Gray (*nomen nudum*, 1840), 1847

Type Species: *Cerithium mesal* Adanson, 1757 [= *Turritella mesal* Deshayes, 1843], by original designation; Recent, southern Portugal, southwestern Spain, Alboran Sea, Canary Islands, Senegal, and western Turkey.

Description: Small to large (up to approximately 95 mm shell height), turritelliform, slender to conical rotund. Pleural angle ranges from 15° to 41°. Protoconch conical, small, smooth, and approximately two whorls. Protoconch to teleoconch transition gradual. Teleoconch whorls up to 16, whorl sides convex to flattish/concave. Sculpture on early juvenile teleoconch whorls variable, ranging from nearly smooth or with very fine, unicostate, bicostate, or tricostrate spiral lirae; sculpture on adult

whorls highly variable, ranging from smooth to numerous, weak to moderately strong closely spaced spiral ribs, but less commonly with fewer and more prominent spiral ribs. Growth lines parasigmoidal on last whorl (including base); lateral sinus variable in amount of concavity (flexure). Aperture with shallow effuse spout, ranging from somewhat constrained to broad. Adapical edge of spout usually forms weak spiral ridge that continues onto columella.

Discussion: *Mesaliopsis* Thiele, 1929 [type species: *Mesalia opalina* (Adams and Reeve, 1850)], Recent, was reported by Wenz (1939) to be a subgenus of *Mesalia*, but future work might show it to be synonymous with *Mesalia*.

Mesalia somewhat resembles *Lithotrochus* Conrad, 1855, of Jurassic age from Chile, South America. Cossmann (1912: 125) reported *Lithotrochus* to be a junior synonym of *Mesalia*, but Wenz (1938: 280, fig. 596) and Cox (1960: 1248–1249, fig. 159,11) believed *Lithotrochus* to be a trochid. It is an extraordinarily large gastropod (height 125 mm) with a wide pleural angle, domed upper spire, turritelliform shape, anteriorly carinate whorls, and relatively few spiral ribs. Details of its aperture are unknown.

Cossmann (1912: 125) also reported *Lithotrochus* to be a junior synonym of *Arcotia* Stoliczka, 1868, whose type species, *Arcotia indica* Stoliczka (1868: 215, 469, pl. 16, figs. 12, 12a; pl. 19, fig. 6) is from Upper Cretaceous (Trichinopoly Group) strata near the town of Alundapooram, southern India. According to Sundaram et al. (2001: fig. 3), this town's name is also referred to as Alundalippur and, from information in their map, this town is underlain by the Kulakkalnattam Formation of Turonian age. Wenz (1939) synonymized *Arcotia* with *Mesalia*. Finlay and Marwick (1937) reviewed the morphology of *Arcotia* and reported that, based on its straight growth lines and open umbilicus, this genus is not a synonym of *Mesalia*. They reported, furthermore, that *Arcotia* appears to be a mathildid. Bandel (2000) came to the same conclusion.

Mesalia is similar to the pareorine *Woodsalia* Olsson 1929, whose type species, *Woodsalia negritosensis* Olsson (1929: 13–15, pl. 4, figs. 5, 6) is from lower Eocene rocks in northwestern Peru. Woods (1922: 78–79, pl. 7, figs. 5–7; pl. 8, figs. 1–3) and Wenz (1939: 651, fig. 1852, two views) also illustrated this species. The full shape of the aperture of this Peruvian gastropod, however, is not known.

Genus *Sigmesalia* Finlay and Marwick, 1937, was originally erected to accommodate a group of Eocene gastropods from the Paris Basin, France that were previously identified as *Mesalia*. There has been no consensus as to whether or not *Sigmesalia* is a distinct genus. Marwick (1957) reported it to be a separate genus, as did Le Renard (1994). Eames (1952) reported it to be a subgenus of *Mesalia*, and Palmer and Brann (1966) reported *Sigmesalia* to be synonymous with *Mesalia*.

Various views of representative specimens of the type

species of *Mesalia* are illustrated in Figures 3–9, and various views of a representative specimen of the type species of *Sigmesalia* are illustrated in Figures 10–13. Its type species, *Sigmesalia koeneni* Le Renard, 1994 [new name for *Turritella sulcata* Lamarck, 1804 (original designation), *non* Bosc, 1801], is of middle Eocene (Lutetian) age and from Paris Basin, France. Finlay and Marwick (1937) stated that the aperture and growth lines of the type species of *Mesalia* seem to be generically different than those of the Paris Basin shells, but they did not provide any details. Davies (1971: 312, figs. 677a, 677b) mentioned that the growth lines of *Sigmesalia* have a more flexed outer lip sinus than does *Mesalia*. According to Marwick (1957: 163), *Sigmesalia* differs from *Mesalia* by usually having a wider pleural angle. The following paragraphs deal with our observations concerning these proposed diagnostic features of *Sigmesalia*.

Inspection of representative specimens of several of the Eocene Paris Basin species, including the type species of *Sigmesalia*, stored in the LACMIP collection, as well as inspection of photographs of 17 Paris Basin species (see Cossmann and Pissarro, 1910–1913: pl. 21, figs. 126–1 to 126–15), revealed variability in the shape of the aperture of *Sigmesalia*. For example, the aperture of *Sigmesalia incerta* (Deshayes, 1832; Cossmann and Pissarro, 1910–1913: pl. 21: fig. 126–4, two views) is similar to that of *M. mesal*, in that the spout is broad and not well constrained. The aperture of *Sigmesalia koeneni* however, is better developed (Cossmann and Pissarro, 1910–1913: pl. 21, fig. 126–15).

The amount of flexure of the outer lip sinus is basically similar in all the Eocene Paris Basin species, although *Mesalia solida* (Deshayes, 1861) does show some variability. The amount of flexure of this feature is variable in *M. mesal* and can be similar to the amount seen on Eocene Paris Basin species. Variability in the amount of flexure for both the Eocene and modern *Mesalia* shells can also occur in proximity of growth checks and break-ages of the outer lip incurred during the life of the gastropod.

The pleural angle of the Eocene Paris Basin shells is quite variable, ranging from 21° to 41°, but the low end of this range [e.g., *Mesalia ecki* (Laubrière, 1881; Cossmann and Pissarro, 1910–1913: pl. 21, fig. 126–2)] is very close to the value (16° to 18°) on *M. mesal*. *Sigmesalia koeneni* has one of widest pleural angles (41°; see Figures 10 and 12). For comparative purposes, an illustration (Figure 14) is provided for *Sigmesalia solida*. It has a relatively narrow pleural angle of 25°, more like that found on *M. mesal* (Figures 3, 4, and 7).

Other morphologic features that are variable on the Eocene Paris Basin shells are strength and number of spiral ribs, pattern of development of sculpture on the early juvenile teleoconch whorls, and degree of indentation of the suture. Even the strength of the spiral ridge (Figure 10) on the columella is variable. *Mesalia mesal* possesses a spiral ridge on the columella, as do most specimens of *Sigmesalia koeneni* (compare Figures 8 and 11).

A few species of *Sigmesalia* are similar to *Mesalia* in having a relatively narrow pleural angle and bicostate sculpture on the early juvenile whorls but not on the adult whorls. They are the following: *Sigmesalia instabilis* (Briart and Cornet, 1873: 86, pl. 12, figs. 9a–9b) of early Paleocene (Danian) age from Belgium; *Sigmesalia salvani* (Adegoke, 1977: 86–88, pl. 14, figs. 10–16) of Paleocene age from Nigeria; and *Sigmesalia fasciata* (Lamarck, 1804: 217) from Eocene strata in France, Belgium, and Pakistan (Cossmann and Pisarro, 1910–1913; Cox, 1930; Eames, 1952); *Sigmesalia pagoda* (Cox, 1930: 160–161, pl. 18, figs. 6a–b, 7a–b) from Eocene strata in Pakistan; *Sigmesalia biplicata* (Bowles, 1939: 328, pl. 34, figs. 6, 8) from Paleocene strata in Alabama; and *Sigmesalia gomin* (Bowles, 1939: 326–327, pl. 33, fig. 9) from Paleocene strata in South Carolina.

The protoconchs of *Mesalia mesal* and *Sigmesalia solida* are very similar (compare Figures 5 and 15); both are small, smooth, have essentially the same shape, and the transition to the teleoconch is gradual.

In summary, we found that the morphologic features of the Eocene Paris Basin shells are variable. We could find no reliable, constant morphologic characters to distinguish *Mesalia* from *Sigmesalia*; hence, we regard them as congeneric.

Mesalia martinezensis (Gabb, 1869)
(Figures 16–23)

Turritella martinezensis Gabb, 1869: 169–170, 228, pl. 28, fig. 51; Dickerson, 1914a: pl. 13, fig. 10; Waring, 1917: 100, pl. 14, fig. 5.

Turritella maccreeadyi Waring, 1914: 783; Waring, 1915: fig. 15 [not fig. 14]; Waring 1917: 87–88, pl. 12, fig. 10.

Mesalia maccreeadyi (Waring).—Paredes-Mejia, 1989: 176–177, pl. 3, figs. 3–6.

Mesalia martinezensis (Gabb).—Cossmann, 1912: 126; Stewart, 1927: 353–354, pl. 25, fig. 1; Schenck and Keen, 1940: pl. 20, fig. 5; Merriam, 1941: 127–128, pl. 39, figs. 1–5, 7; Zinsmeister, 1974: 118–119, pl. 12, figs. 5, 9; Zinsmeister, 1983: pl. 2, fig. 14; Paredes-Mejia, 1989: 173–176, pl. 3, figs. 7–10; Saul, 1983a: text-fig. 2, pl. 1, fig. 2.

Mesalia clarki (Dickerson).—Zinsmeister, 1983: pl. 2, fig. 13.

Description: Large (up to approximately 95 mm height). Turritelliform. Pleural angle approximately 20°. Protoconch unknown. Teleoconch up to 12 whorls, increasing rapidly in size from the apex. Suture slightly impressed. Sculpture consisting only of spiral ribs of differing strength but dominated by carina located anteriorly; ribs generally becoming stronger with growth; spiral threads on interspaces and on carina surface. Carina usually strongly angulate but can be rounded or even subdued. Posterior to carina, several widely spaced spiral ribs of variable strength occur, ranging from tertiaries to primaries: two ribs on uppermost spire, three to four on upper spire, and one to three on lower spire. Anterior to carina, several spiral ribs of variable strength occur, ranging from tertiaries to primaries: approximately five ribs on upper spire and one to two ribs (both occasionally

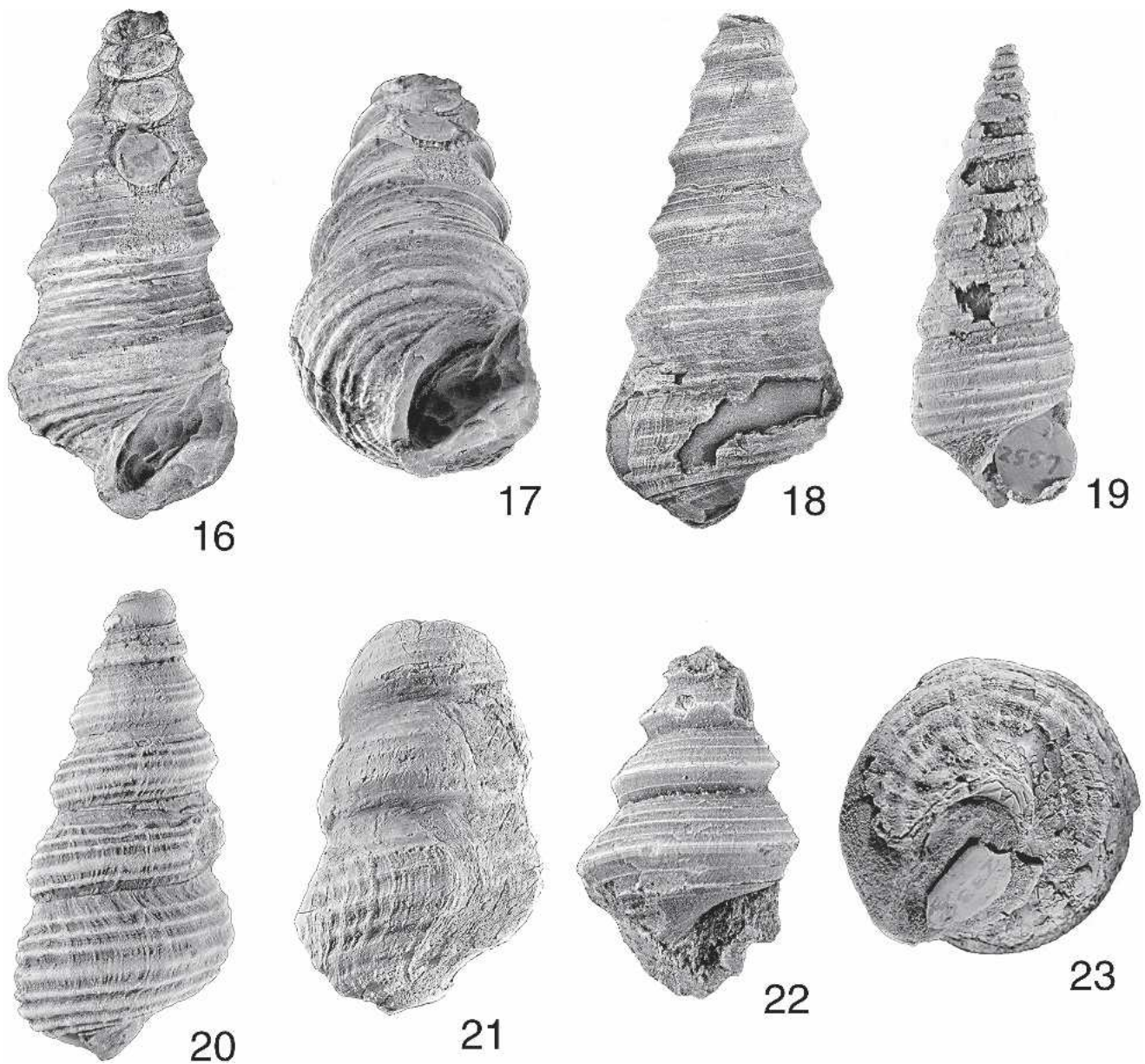
quite prominent) on lower spire. Last whorl with three primaries, both posterior and anterior to carina. Base with three secondaries, anteriormost one weak; ribs obsolete on short neck. Aperture relatively small, D-shaped; columella relatively broad, smooth; spout effuse and short with anterior end projecting slightly; growth-line trace of last whorl (including base) parasigmoidal, with lateral sinus flexure strongest in vicinity of carina.

Holotype: ANSP 4344, height 57 mm, diameter 23 mm.

Type Locality: Martinez, northern California (details not given).

Geologic Range: Late early Paleocene to early late Paleocene (near the Danian-Selandian boundary to early Thanetian).

Distribution: DANIAN = *Turritella peninsularis qualey* Zone: lower San Francisquito Formation, Warm Springs Mountain, Los Angeles County, southern California (new stratigraphic occurrence, LACMIP loc. 21581). NEAR THE DANIAN-SELANDIAN BOUNDARY = *Turritella peninsularis qualey* Zone transitional with *Turritella peninsularis* Zone: Martinez Formation, Herndon Creek east of Lower Lake, Lake County, northern California (Stanton, 1896 [faunal list]; Dickerson, 1914a; Merriam, 1941); upper Las Virgenes Sandstone, Simi Hills, Ventura County, southern California (Waring, 1917; Nelson, 1925 [faunal list]; Merriam, 1941; Zinsmeister, 1983; Saul, 1983a). PROBABLY NEAR THE DANIAN-SELANDIAN BOUNDARY: Reworked specimens in Santa Susana Formation, Poison Oak Canyon, north side Simi Valley, Los Angeles County, southern California (new stratigraphic occurrence, LACMIP loc. 21554); Reworked specimens in Stokes Canyon Breccia Member of the middle Miocene Calabasas Formation, Stokes Canyon, Santa Monica Mountains, Ventura County (new stratigraphic occurrence, LACMIP loc. 25281). SELANDIAN = *Turritella peninsularis* Zone: Lower Vine Hill Sandstone, Martinez area, Contra Costa County, northern California (Weaver, 1953 [faunal list]); lower San Francisquito Formation, Pinyon Ridge east of Big Rock Creek, Valymero area, Antelope Valley, Los Angeles County, southern California (Dickerson, 1914b [faunal list]; Merriam, 1941; Kooser, 1980 [faunal list]); lower Santa Susana Formation (= “Martinez marine member” of Nelson, 1925 [faunal list]), Simi Hills, Ventura County, southern California (Kew, 1923 [faunal list]; Nelson, 1925 [faunal list]; Zinsmeister, 1983; Saul, 1983a). LOWER THANETIAN = *Turritella infragranulata* Zone: Upper Vine Hill Sandstone, Martinez area, Contra Costa County, northern California (Weaver, 1953 [faunal list]); upper Santa Susana Formation, Palisades Highlands, Santa Monica Mountains, Los Angeles County, southern California (new stratigraphic occurrence, LACMIP locs. 7060 and 11717); Sepultura Formation, Mesa San Carlos, northern Baja California, Mexico (Paredes-Mejia, 1989).



Figures 16–23. *Mesalia martinezensis* (Gabb, 1869). Specimens coated with ammonium chloride. **16–18.** Hypotype LACMIP 13399, height 58 mm, diameter 25.4 mm. **16.** Apertural view. **17.** Oblique apertural view. **18.** Abapertural view. **19.** Hypotype LACMIP 13400, LACMIP loc. 22557, apertural view, height 36.3 mm, diameter 14.1 mm. **20.** Hypotype LACMIP 13401, LACMIP loc. 21607, abapertural view, height 38.3 mm, diameter 19.3 mm. **21.** Hypotype LACMIP 13402, LACMIP loc. 22698, abapertural view, height 33.9 mm, diameter 21.6 mm. **22.** Hypotype LACMIP 13403, LACMIP loc. 26897, apertural view, height 10.6 mm, diameter 6.5 mm. **23.** Hypotype LACMIP 13404, LACMIP loc. 22330, base, diameter 17.2 mm.

Discussion: The largest specimens of this species occur in the lower San Francisquito Formation, Pinyon Ridge east of Big Rock Creek, Valmoro area, Antelope Valley, Los Angeles County, southern California.

There is considerable variability in the strength of the spiral ribs on *M. martinezensis*. Most specimens are carinate on all whorls, including the last whorl. On some specimens, however, the carina becomes weaker on the later whorls as the other spiral ribs become stronger, giving these whorls a convex shape (Figures 19–21), like

shells misidentified by some workers as *Turritella macleadyi* Waring, 1914.

The overall teleoconch morphology of the 10 mm-high tip of *Mesalia martinezensis* superficially resembles that of the 15-mm high mathildid *Carinathilda diminuta* (Perrilliat, Vega, and Corona, 2004) illustrated by Kiel et al. (2002: 329–330, fig. 2.4) from the lower Maastrichtian of the Mexcala Formation, Guerrero, southern Mexico. *Carinathilda diminuta* is definitely a mathildid because it has a heterostrophic protoconch. The resemblance be-

tween these two gastropods, nevertheless, provides evidence that the Late Cretaceous mathildids and lower Paleogene turritellids can have similar looking adult shells.

Mesalia martinezensis resembles "*Mesalia*" *virginiae* Stilwell et al. (2004: 29–30, pl. 5, figs. 6–10) from lower Paleocene (Danian) rocks on Seymour Island, Antarctic Peninsula, but *M. martinezensis* has a subtle effuse spout rather than the longer and more distinct, twisted narrow anterior canal that "*M. virginiae*" possesses. In addition, *M. martinezensis* has stronger ribs and a parasigmoidal growth line, rather than an opisthocyrt one on the last whorl. In our opinion, the aperture of "*M. virginiae*" is unlike that of *Mesalia*.

Gabb (1869) mentioned that the broadly expanding whorl of *martinezensis* approaches that seen on *Turritella robusta* Gabb (1864: 135, pl. 21, fig. 74; not = *T. (Haustator) robusta* Grzybowski, 1899), but Merriam (1941: 128) reported that the Late Cretaceous *T. robusta*, which is represented by a single poorly preserved type specimen, is probably not a *Mesalia*. This type specimen has an umbilicus, therefore it is not a turritellid. It is from the Redding area, northern California, and not from Tuscan Springs, as erroneously reported by Merriam (1941). Jones et al. (1978: pl. 1, fig. 19) identified this specimen, which is of Turonian age, to be *Glauconia?* *robusta* (Gabb, 1864).

Merriam (1941: 10, 116) stated that mainly in profile the Pacific slope Miocene *Turritella temblorenensis* Wiedey, 1928, might readily be confused with *Mesalia martinezensis*. The latter also resembles the Pacific slope Miocene *Turritella temblorenensis tritschi* Hertlein, 1928, and *Turritella ocoyana* Conrad, 1857. The latter, however, has a different growth line. In addition, *T. martinezensis* strongly resembles *Turritella fredeai* Hodson, 1926, of Miocene age from northern Colombia and northern Venezuela. None of these above-mentioned Miocene species, however, has the effuse spout of *Mesalia*.

Mesalia clarki (Dickerson, 1914a)
(Figures 24–32)

Turritella [sic] *clarki* Dickerson, 1914a: 142–143, pl. 13, fig. 8.
Mesalia clarki (Dickerson).—Merriam, 1941: 128, pl. 39, fig. 6;
Zinsmeister, 1983: table 1, pl. 2, fig. 14.

Description: Medium small (up to approximately 31 mm height). Turritelliform. Pleural angle approximately 21 to 22°. Protoconch unknown. Teleoconch up to 12 whorls, consisting of two whorl shapes: flatish rounded and anteriorly angulate. Sutural area indented. Sculpture consisting only of spiral ribs, variable in number, strength, and spacing. Flattish to rounded whorl shape: upper spire with one or two secondaries on posterior part and two (bicostate) primaries on anterior part; lower spire and last whorl with seven to eight nearly equal

strength primaries (anteriorly located ribs can be somewhat angulate); spiral threads on all interspaces; posteriormost rib part of broad band; ribs on anterior part of whorl tend to be slightly stronger than posteriorly located ribs; base of last whorl with three ribs. Angulate whorl shape: upper spire with one secondary on posterior part and two (bicostate), well developed, flat-topped primaries on anterior part; lower spire and last whorl with three primaries on posterior part and two stronger primaries, with one secondary in between each, on anterior part; spiral threads on all interspaces. Base (including short neck) of last whorl with approximately seven, evenly spaced ribs; interspaces and ribs covered by spiral threads. Aperture small; columella narrow with thin callus, occasionally with single, weak fold, slight twist on anterior end of columella. Spout effuse, short, and narrow. Growth-line trace on last whorl (including base) parasigmoidal, with lateral sinus flexure strongest medially.

Holotype: UCMP 11936, height 25 mm, diameter 16.5 mm.

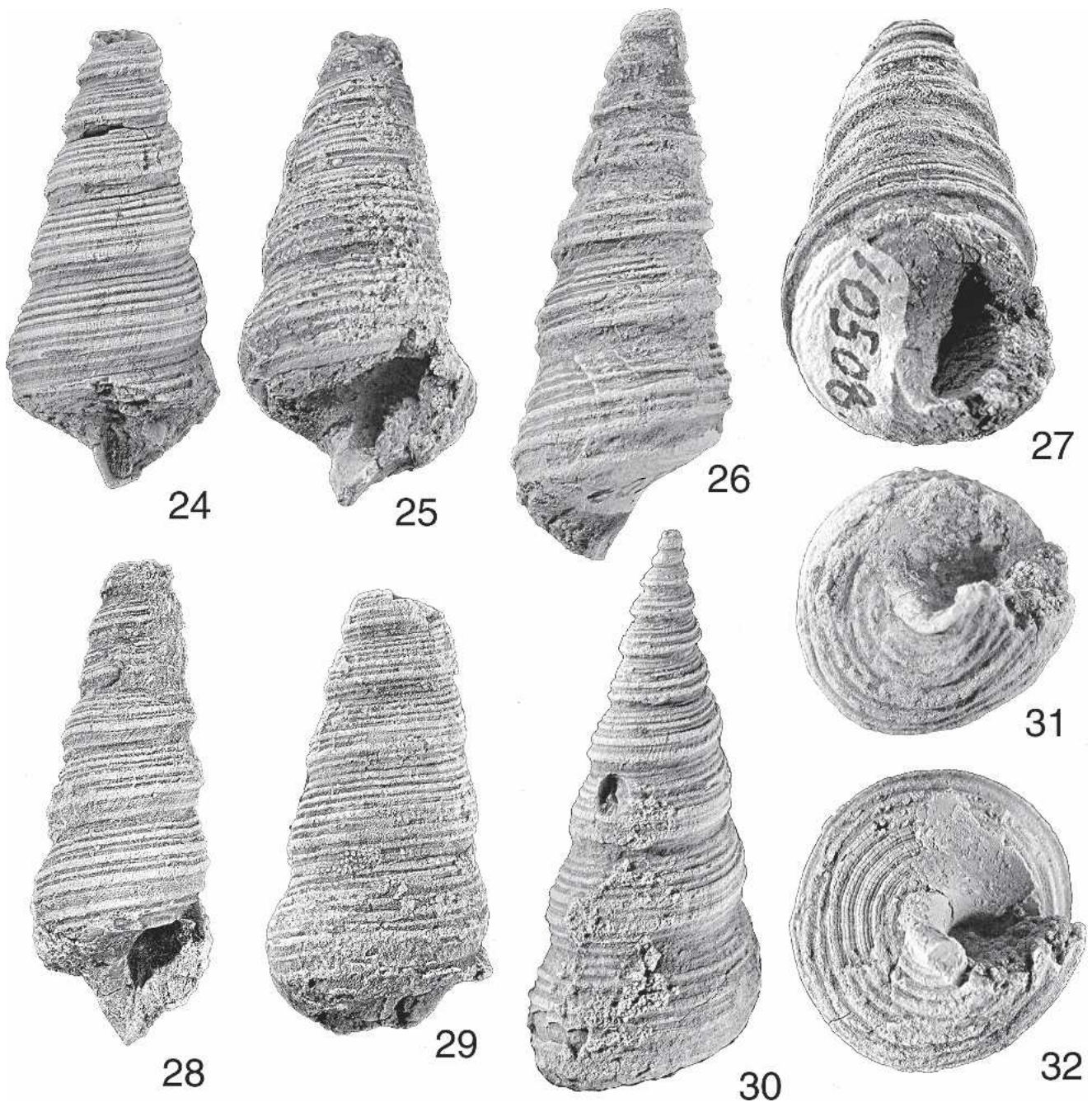
Type Locality: UCMP loc. 1540.

Geologic Range: Late Paleocene = *Turritella infra-granulata* Zone.

Distribution: "Martinez" Formation, northeast side of Mount Diablo, Contra Costa County, northern California (Dickerson, 1914a; Merriam, 1941; Zinsmeister and Paredes-Mejia, 1988 [faunal list]; upper Santa Susana Formation, Trailer and Quarry canyons, Los Angeles County, Santa Monica Mountains, southern California (Strathearn et al., 1988 [faunal list]; Squires and Saul, 1998: 1025).

Discussion: *Mesalia clarki* is abundant in the upper Santa Susana Formation at LACMIP loc. 10508, in the Santa Monica Mountains, Los Angeles County, southern California. The anterior ends of the shells are very fragile, and nearly all the specimens have incomplete apertures. None of the specimens has retained their protoconch, and most specimens are missing their upper spire. Growth lines are hard to discern, usually visible only on a single whorl (typically the penultimate whorl), and were rarely preserved on the base of the last whorl. Some of the specimens appear to have a wider pleural angle (23°) than normal, but these particular specimens have been crushed. A few of the specimens (five percent) have naticid boreholes, and a few other specimens are encrusted, in part, by bryozoans. Rare specimens are coated by calcareous algae.

All previous workers assigned *Mesalia clarki* to various genera without knowledge of the shape of the aperture. Our cleaning of representative specimens of Dickerson's species revealed it to have a short, shallow effuse spout (Figures 24–25) and bicostate sculpture on the juvenile whorls (Figure 30). There is considerable variation in the sculpture and the shape of the whorls on *M. clarki*. Some



Figures 24–32. *Mesalia clarki* (Dickerson, 1914). Specimens coated with ammonium chloride. All from LACMIP loc. 10508. **24.** Hypotype LACMIP 13405, apertural view, height 21.5 mm, diameter, 19.6 mm. **25.** Hypotype LACMIP 13406, slightly oblique apertural view, height 23.1 mm, diameter 10.8 mm. **26–27.** Hypotype LACMIP 13407, height 22.6 mm, diameter 9.4 mm. **26.** Abapertural view. **27.** Oblique apertural view. **28.** Hypotype LACMIP 13408, apertural view, height 23.2 mm, diameter 9.2 mm. **29.** Hypotype LACMIP 13409, abapertural view, height 21.5 mm, diameter 11 mm. **30.** Hypotype LACMIP 13410, abapertural view, height 23.6 mm, diameter 9.7 mm. **31.** Hypotype LACMIP 13411, base, diameter 9.5 mm. **32.** Hypotype LACMIP 13408, base of same specimen shown in Figure 28, diameter 8.9 mm.

specimens have nearly uniform sculpture and flattish whorls (Figure 24), others have carinate whorls (Figure 26), whereas others have uniform sculpture with convex whorls (Figure 29).

Zinsmeister (1983: pl. 2, fig. 14), Zinsmeister and Paredes-Mejia (1988: table 1), and Paredes-Mejia (1989: table 3) reported *M. clarki* from the Santa Susana Formation in the Simi Hills, southern California. These re-

ports, however, were based on the misidentification of a specimen of *Mesalia martinezensis* that happens to lack a strong anterior carina on the otherwise convex whorls.

Mesalia clarki resembles *Motyris aralica* (Michailovski, 1912; Wenz, 1939: 652, fig. 1856) from upper Eocene rocks in the Aral Sea region. *Motyris* Eames, 1952, was formerly known as *Tomyris* Michailovski, 1912. See Marwick (1957: 162–163) for more taxonomic information about *Motyris*. *Mesalia clarki* differs from *M. aralica* by not having tabulate whorls with strongly indented sutures. The full aperture of *M. aralica* is unknown, and details about its apical whorl development are wanting. The only other species of *Motyris* that we are aware of is *Motyris pseudoaralica* Eames (1952: 30–31, pl. 1, fig. 15; pl. 2, figs. 58a, b) from Pakistan, but its aperture is unknown. We believe that when the great variability of *Mesalia* is taken into account, *Motyris* will prove to be congeneric.

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LITERATURE CITED

- Abbass, H. L. 1963. A monograph on the Egyptian Cretaceous gastropods. United Arab Republic, Ministry of Industry, Geological Survey and Mineral Research Department, Geological Museum, Palaeontological Series Monograph 2, 146 pp.
- Abbott, P. L., D. P. Smith, W. V. Sliter, and L. R. Saul. 1995. Paleogeography of three Paleocene limestones in Baja California, Mexico. In: A. E. Fritsche (ed.) *Cenozoic Paleogeography of the Western United States—II. Pacific Section* (Society for Sedimentary Geology), Book 75: 1–8.
- Adams, A. and L. A. Reeve. 1848–1850. *Mollusca*. In: A. Adams (ed.) *The Zoology of the Voyage of H. M. S. Samarang, under the Command of Captain Sir Edward Belcher . . . During the Years 1843–1846*. Reeve et al., London, x + 87 pp.
- Adanson, M. 1757. *Histoire naturelle du Sénégal: Coquillages, avec la relation abrégée d'un voyage fait ce pays, pendant les années 1749–53*. Bauche, Paris, 2 Parts: Voyage, viii + 190 pp.; Coquillages, xcvi + 275 pp.
- Adegoke, O. S. 1977. Stratigraphy and paleontology of the Ewekoro Formation (Paleocene) of southwestern Nigeria. *Bulletins of American Paleontology* 71(295): 1–379.
- Afonso, C. M. L., P. M. M. Morenito, and F. F. L. M. Titselaar. 2000. Collecting shells in “Ria Formosa,” a coastal lagoon system in southern Portugal. *Vita Marina* 47: 9–17.
- Aldrich, T. H. 1894. The (Midway) Clayton Tertiary section and its fossils. In: E. Smith, J. Allen, C. Lawrence and D. W. Landgon, Jr., *Report on the Geology of the Coastal Plain of Alabama*. Alabama Geological Survey, 759 pp.
- Allison, E. C. 1955. Middle Cretaceous Gastropoda from Punta China, Baja California, Mexico. *Journal of Paleontology* 29: 400–432.
- Allmon, W. D. 1996. Systematics and evolution of Cenozoic American Turritellidae (Mollusca: Gastropoda) I: Paleocene and Eocene coastal plain species related to “*Turritella mortoni* Conrad” and “*Turritella humerosa* Conrad.” *Palaeontographica Americana* 59: 1–134.
- Alves, F. L. Chicharo, A. Nogueira and J. Regala. 2003. Changes in benthic community structure due to clam dredging on the Algarve coast and the importance of seasonal analysis. *Journal of the Marine Biological Association of the United Kingdom* 83: 719–729.
- d'Archiac, A. and H. Haime. 1854. Description des animaux fossiles du groupe nummulitique de l'Inde. Guide et J. Baury, Paris, pp. 225–373.
- Ardevini, R. and T. Cossignani. 2004. West African seashells (including Azores, Madeira and Canary Is.). Volume 2. L'Informatore Piceno, Ancona, Italy, 319 pp.
- Bandel, K. 2000. Some gastropods from the Trichinopoly Group Tamil Nadu, India and their relation to those from the American Gulf Coast. *Geological Society of India, Memoir* 46: 65–111.
- Barthel, K.W. and W. Herrmann-Degen. 1981. Late Cretaceous and early Tertiary stratigraphy in the Great Sand Sea and its SE margins (Farafra and Dakhla oases), SW Desert, Egypt. *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie* 21: 141–182.
- Bosc, L. A. G. 1801. *Histoire naturelle des coquilles*. In: G. L. L. de Buffon (ed.) *Histoire naturelle de Buffon, etc., nouvelle édition*. Mollusca: Volume 4. Déterville, Paris, 280 pp.
- Bouchet, P. 1977. Distribution des mollusques dans les mangroves du Sénégal. *Malacologia* 16: 67–74.
- Bouchet, P., J. Fryda, B. Hausdorf, W. Ponder, Á. Valdés and A. Warén. 2005. Working classification of the Gastropoda. In: P. Bouchet and J.-P. Rocrois (eds.) *Classification and Nomenclator of Gastropod Families*. *Malacologia* 47: 239–284.
- Bowles, E. 1939. Eocene and Paleocene Turritellidae of the Atlantic and Gulf coastal plain of North America. *Journal of Paleontology* 13: 267–336.
- Brabb, E. E., H. S. Sonnemap and J. R. Switzer, Jr. 1971. Preliminary geologic map of the Mount Diablo-Bryon area, Contra Costa, Alameda and San Joaquin counties, California. U. S. Geological Survey Open File Map 71-53 (scale 1:62,500).
- Briart, A. and F.-L. Cornet. 1873. Description des fossiles du Calcaire grossier de Mons. Gastéropodes. *Mémoires Couronnés et Mémoires des Savants étrangers, l'Académie Royale des Sciences, des lettres et des Beaux-arts de Belgique*, Part 2, 37: 1–94.
- Colburn, I. P. 1996. Stratigraphic and sedimentary structures of the Paleogene successions in the west central Santa Monica Mountains, Los Angeles County, California. In: P. L. Abbott and J. D. Cooper (eds.) *Field Conference Guide 1996*. Pacific Section, SEPM Book 80, pp. 93–116.
- Conrad, T. A. 1855. Remarks on the fossil shells from Chili, collected by Lieut. Gilliss, with description of the species. Appendix H. U. S. Naval Astronomy Expedition to the

- Southern Hemisphere during 1849–52. U. S. 33rd Congress, First Session, House Document 121, Volume 2: 282–286.
- Conrad, T. A. 1857. Description of the Tertiary fossils collected on the survey [Williamson's survey]. In: Reports of Explorations and Surveys . . . Route for a Railroad from the Mississippi River to the Pacific Ocean. U. S. 34th Congress, First Session, Senate Executive Document 78, House Executive Document 91, Volume 5, pt. 2, appendix, article 2: 317–329.
- Cossmann, M. 1912. Essais de paléoconchologie comparée. Volume 9. Privately published, Paris, 216 pp.
- Cossmann, M. and G. Pissarro. 1910–1913. Iconographie complétée des coquilles fossiles de l'Eocène des environs de Paris. Société Géologique de France. Volume 2 (Gastropodes, etc.). Paris, 65 pls.
- Cotton, B. C. 1932. Notes on Australian Mollusca, with descriptions of new genera and new species. Records of the South Australian Museum 4: 537–547.
- Cox, L. R. 1930. The fossil faunas of the Samana Range and some neighbouring areas: Part 8. The Mollusca of the Hangu Shales. Palaeontologica Indica, Memoirs of the Geological Survey of India, New Series, 15: 129–222.
- Cox, L. R. 1960. General characteristics of Gastropoda. In: R. C. Moore (ed.) Treatise on Invertebrate Paleontology. Part I, Mollusca. Geological Society of America and University of Kansas Press, pp. I84–I69.
- Davies, A. M. 1971. Tertiary faunas, a text-book for oilfield palaeontologists and students of geology, Volume 1, The composition of Tertiary faunas, revised by F. E. Eames and R. J. G. Savage. Second ed. George Allen & Unwin Ltd., London, 571 pp.
- Davies, A. M. 1975. Tertiary faunas, a text-book for oilfield palaeontologists and students of geology, Volume 2, The sequence of Tertiary faunas, revised by F. E. Eames and R. J. G. Savage. Second ed. George Allen & Unwin Ltd., London, 447 pp.
- Demir, M. 2003. Shells of Mollusca collected from the seas of Turkey. Turkish Journal of Zoology 27: 101–140.
- Deshayes, G. P. 1832. Description des coquilles fossiles des environs de Paris. Volume 2. Livraisons 27–29. Levrault, Paris, pp. 163–290.
- Deshayes, G. P. 1843. Histoire naturelle des animaux sans vertèbres. Second ed., Volume 9. J.-B. Baillière, Paris, 728 pp.
- Deshayes, G. P. 1861. Description des animaux sans vertèbres découverts dans le bassin de Paris. Volume 2; Atlas, pt. 2. J.-B. Baillière et fils, Paris, pp. 1–432.
- Dickerson, R. E. 1914a. Fauna of the Martinez Eocene of California. University of California Publications Bulletin of the Department of Geology 8(6): 61–180.
- Dickerson, R. E. 1914b. The Martinez Eocene and associated formations at Rock Creek on the western border of the Mohave Desert area. University of California Publications, Bulletin of the Department of Geology 8(14): 289–298.
- Dockery, D. T., III. 1986. Punctuated succession of Paleogene mollusks in the northern Gulf Coastal plain. Palaios 1: 582–589.
- Douvillé, H. 1904. Paléontologie, mollusques fossiles. In: J. De Morgan, Mission Scientifique en Perse, Volume 3, part 4. E. Leroux, Paris, pp. 191–380.
- Douvillé, H. 1928. Les couches à *Cardita beaumonti*. Fascicule 1. Memoirs of the Geological Survey of India, Palaeontologica Indica, New Series, Volume 10, Memoir 3: 1–72.
- Eames, F. E. 1952. Description of the Scaphopoda and Gastropoda of the western Punjab and in the Kohat district. Philosophical Transactions of the Royal Society of London, Series B, 236: 1–168.
- Finlay, H. J. and J. Marwick. 1937. The Wangaloan and associated molluscan faunas of Kaitangata-Green Island subdivision. New Zealand Geological Survey, Palaeontological Bulletin 15, 140 pp.
- Fleming, J. 1822. The philosophy of zoology or a general view of the structure, functions and classification of animals, etc. Volumes 1 and 2. Edinburgh, 618 pp.
- Forbes, E. 1846. Report on the fossil Invertebrata from South India collected by MM. Kaye and Cunliffe. Transactions of the Geological Society of London, Series 2, 7: 97–174.
- Gabb, W. M. 1860. Descriptions of new species of American Tertiary and Cretaceous fossils. Journal of The Academy of Natural Sciences of Philadelphia, Series 2, 4(4): 375–406.
- Gabb, W. M. 1864. Descriptions of the Cretaceous fossils. Geological Survey of California, Palaeontology 1(4): 57–217.
- Gabb, W. M. 1869. Cretaceous and Tertiary fossils. Geological Survey of California, Palaeontology 2: 1–299.
- Glibert, M. 1973. Revision des Gastropoda du Danien et du Montien de la Belgique. I. Les Gastropoda du Calcaire de Mons. Institut Royal des Sciences Naturelles de Belgique Mémoire 173, 116 pp.
- Gordon, W. A. 1973. Marine life and ocean surface currents in the Cretaceous. Journal of Geology 81: 269–284.
- Gradstein, F. M., J. G. Ogg and A. G. Smith. 2004. A geologic time scale 2004. Cambridge University Press, Cambridge, 589 pp.
- Gray, J. E. 1840. Shells of molluscos animals. In: Synopsis of the contents of the British Museum, edition 42, London, pp. 105–156.
- Gray, J. E. 1847. A list of the genera of Recent Mollusca, their synonyma and types. Proceedings of the Zoological Society of London 15: 129–219.
- Grzybowski, J. 1899. Die Tertiärlagerungen des nördlichen Peru und ihre Molluskenfauna. Neues Jahrbuch für Mineralogie, Geologie und Paläontologies, Beilage, Band 13: 610–664.
- Hanna, G. D. and L. G. Hertlein. 1939. Two new species of gastropods from the middle Eocene of California. Journal of Paleontology 23: 392–394.
- Habe, T. 1955. Notes on the systematic position of the genus *Orectospira* Dall, 1925. Conchological Club of Southern California Minutes 147: 4.
- Haq, B. U. 1981. Paleogene paleoceanography: Early Cenozoic oceans revisited. Oceanologia Acta. Proceedings, 26th International Geological Congress, Geology of Oceans Symposium, Paris, pp. 71–82.
- Hertlein, L. G. 1928. Preliminary report on the paleontology of the Channel Islands, California. Journal of Paleontology 2: 142–157.
- Hidalgo, J. G. 1917. Fauna malacológica de España, Portugal y Las Baleares. Moluscos testáceos marinos. Trabajos del Museo Nacional de Ciencias Naturales, Serie Zoológica, 30, 752 pp.
- Hodson, F. 1926. Venezuela and Caribbean turrinitellas. Bulletin of American Paleontology 11(45): 1–50.
- Hoots, H. W. 1931. Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California. U. S. Geological Survey Professional Paper I65-C: 1–134.
- Johnson, C. C. 1999. Evolution of Cretaceous surface current circulation patterns, Caribbean and Gulf of Mexico. In: E. Barrera and C. C. Johnson (eds.) Evolution of the Creta-

- ceous Ocean-Climate System. Geological Society of America Special Paper 332: 329–343.
- Jones, D. L., W. V. Sliter and W. P. Popenoe. 1978. Mid-Cretaceous (Albian to Turonian) biostratigraphy of northern California. *Annales du Muséum d'Histoire Naturelle de Nice* 4: xx11.1–xx11.13.
- Keen, A. M. and H. Bentson. 1944. Check list of California Tertiary marine Mollusca. Geological Society of America Special Papers 56: 1–280.
- Kew, W. S. W. 1924. Geology and oil resources of a part of Los Angeles and Ventura counties, California. U. S. Geological Survey Bulletin 753: 1–202.
- Kiel, S., K. Bandel, and M. C. Perrilliat. 2002. New gastropods from the Maastrichtian of the Mexcala Formation in Guerrero, southern Mexico, part 2: Archaeogastropoda, Neritimorpha and Heterostropha. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 226: 319–342.
- Kiel, S. and K. Bandel. 2004. The Cenomanian Gastropoda of the Kassenberg quarry in Müllheim (Germany), Late Cretaceous). *Paläontologische Zeitschrift* 78: 103–126.
- Kiener, L. C. 1843. *Spécies général et iconographie des coquilles vivantes, comprenant la collection du Muséum d'Histoire naturelle de Paris*. Pt. 10, Genre *Turritella*. Rousseau et Baillièrre, Paris, 56 pp.
- Kollmann, H. A. and G. S. Odin. 2001. Gastropods from the Upper Cretaceous geological site at Tercis les Bains (SW France). In: G. S. Odin (ed.) *The Campanian-Maastrichtian Stage Boundary*. Elsevier Science, Amsterdam, pp. 437–451.
- Kollmann, H. A. and J. S. Peel. 1983. Paleocene gastropods from Nûgssuaq, west Greenland. *Gronlands Geologiske Undersogelse Bulletin* 146, 115 pp.
- Kooser, M. A. 1980. Stratigraphy and sedimentology of the San Francisquito Formation, Transverse Ranges, California. University of California, Riverside, unpubl. Ph. D. dissertation, 201 pp.
- Lamarck, J. B. 1799. *Prodrome d'une nouvelle classification des coquilles*. Mémoires de la Société d'histoire Naturelle de Paris, pp. 63–91.
- Lamarck, J. B. 1804. *Suite des Mémoires sur les fossiles des environs de Paris*. *Annales de Muséum d'Histoire Naturelle*, Paris, Volumes 4 and 5, variously paged. [Reprinted 1978, Paleontological Research Institution, Ithaca, New York].
- Lamarck, J. B. 1822. *Histoire naturelle des animaux sans vertèbres*. Volume 7, Paris, 711 pp.
- Laubrière, L. B. 1881. Description d'espèces nouvelles du bassin de Paris. *Bulletin de la Société Géologique de France*, Série 3, 9: 277–284.
- Le Renard, J. 1994. Révision des mollusques paléogènes du Bassin de Paris. I-Rectification de nomenclature d'espèces. *Cossmanniana* 3(2): 35–40.
- Locard, A. 1897. Expéditions scientifiques du Travailleur et du Talisman, pendant les années 1880, 1882, 1883. *Mollusques Testacés I*. Masson, Paris, 516 pp., II, 595 pp.
- Lovén, S. L. 1847. *Malacozoologi. Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar (1847)*: 175–199.
- Macedo, M. C. C. and J. P. Borges. *Conchas marinhas de Portugal (Seashells of Portugal)*. Vergo, Lisbon, Portugal, 515 pp.
- Mallory, V. S. 1959. Lower Tertiary biostratigraphy of the California Coast Ranges. *The American Association of Petroleum Geologists, Tulsa, Oklahoma*, 416 pp.
- Maltzan, H. v. 1884. Diagnosen neuer Seneganybischer Gastropoden. *Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft* 16(5): 65–73.
- Marwick, J. 1957. Generic revision of the Turritellidae. *Proceedings of the Malacological Society of London* 32, pt. 4: 144–166.
- Merriam, C. W. 1941. Fossil turritellas from the Pacific coast region of North America. University of California Publications, *Bulletin of the Department of Geological Sciences* 26(1): 1–214, pls. 1–41.
- Michailovski, G. P. 1912. O nekotorych novych ili redkich rakovinach iz treticnych otozenij severnago poberezja aralskago mora. *Sitzungsberichte Naturforscher Gesellschaft Jurjew Dorpat* 21: 120–138.
- Müller, G. 1898. Die Molluskenfauna des Untersenon von Braunschweig und Ilse. I. Lamellibranchiata und Glossopteren. *Atlas zu den Abhandlungen der Königlich Preussischen Geologischen Landesanstalt, Neue Folge* 25, 18 pls.
- Müller, J. 1847–1851. *Monographie der Petrefacten der Aachener Kreideformation*. Henry & Cohen, Bonn, 3 parts, 163 pp.
- Nelson, R. N. 1925. A contribution to the paleontology of the Martinez Eocene of California. University of California Publications, *Bulletin of the Department of Geological Sciences* 15(11): 397–466.
- Olsson, A. A. 1929. Contributions to the Tertiary paleontology of northern Peru, Part 2: Upper Eocene Mollusca and Brachiopoda. *Bulletins of American Paleontology* 15(57): 67–116.
- Olsson, A. A. 1944. Contributions to the paleontology of northern Peru. Part 7. The Cretaceous of the Paita region. *Bulletins of American Paleontology* 28(111): 163–304.
- Palmer, K. V. W. and D. C. Brann. 1966. Catalogue of the Paleocene and Eocene Mollusca of the southern and eastern United States. *Bulletins of American Paleontology* 48(218): 471–1057.
- Paredes-Mejia, L. M. 1989. Late Cretaceous-early Cenozoic stratigraphy and paleontology (Mollusca: Gastropoda) of the Sepultura Formation, Mesa San Carlos, Baja California Norte, Mexico. Purdue University, unpub. M. S. thesis, 527 pp.
- Pasteur-Humbert, C. 1962. Les mollusques marins testacés du Marco. Catalogue non critique. I. Les gastéropodes. *Travaux de l'Institut Scientifique Chérifien, Série Zoologie* 23: 1–224.
- Perrilliat, M. C. 1989. Mollusca. In A. L. Carreño and five others (eds.) *Fósiles tipo mexicanos. Centenario del Instituto de Geología. Universidad Nacional Autónoma de México, Instituto de Geología, México, D. F.*, pp. 117–370.
- Pervinquier, L. 1912. Études de paléontologie Tunisienne. II. Gastropodes et Lamellibranches des terrains Crétacés. Direction Générale des Travaux Publics, Carte Géologique de la Tunisie. J. Lamarre, Paris, xiv + 352 pp.
- Poppe, G. T. and Y. Goto. 1991. *European seashells. Volume 1 (Polyplacophora, Caudofoveata, Solenogastrea, Gastropoda)*. Verlag Christa Hemmen, Wiesbaden, Germany, 352 pp.
- Quaas, A. 1902. Beiträge zur Kenntniss der Fauna der obersten Kreidebildung in der libyschen Wüste. II. Die Fauna der Überwiegendichten und der Blätterthone in der libyschen Wüste. *Palaeontographica* 30 (2): 153–334.
- Reeve, L. A. 1849. *Conchologia iconica; or illustrations of the shells of molluscous animals*. Volume 5, 147 pls.
- Roemer, F. 1849. Texas, mit besonderer rücksicht auf

- Deutsche Auswanderung und die physischen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 469 pp.
- Saul, L. R. 1983a. Notes on Paleogene turritellas, venericardias, and molluscan stages of the Simi Valley area, California. In: R. L. Squires and M. V. Filewicz (eds.) Cenozoic Geology of the Simi Valley Area, Southern California. Pacific Section, SEPM Fall Field Trip Volume and Guidebook, Book 35, pp. 71–80.
- Saul, L. R. 1983b. *Turritella* zonation across the Cretaceous-Tertiary boundary, California. University of California Publications Geological Sciences 125: x + 1–165.
- Saul, L. R. 1986. Pacific west coast Cretaceous molluscan faunas: Time and aspect of changes. In: P. L. Abbott (ed.) Cretaceous Stratigraphy Western North America. Pacific Section, Book 46: 131–135.
- Saul, L. R. and R. L. Squires. 1997. New species of neritid gastropods from Cretaceous and Lower Cenozoic strata of the Pacific slope of North America. *The Veliger* 40: 131–147.
- Schenck, H. G. and A. M. Keen. 1940. California fossils for the field geologist. Preliminary ed. Stanford University, Stanford, California, 86 pp.
- Serra, G. 1937. Di alcune Turritellidae del Maestrichtiano della Tripolitania. *Bollettino della Società Geologica Italiana* 61: 303–316.
- Smith, E. A. 1915. On the genera *Eglisia*, *Callostracum*, *Mesalia*, *Turritellopsis*, and *Tachyrhynchus*. *Annals and Magazine of Natural History* 15: 360–377.
- Squires, R. L. 1987. Eocene molluscan paleontology of the Whitaker Peak area, Los Angeles and Ventura counties, California. *Natural History Museum of Los Angeles County, Contributions in Science* 388: 1–93.
- Squires, R. L. 1997. Taxonomy and distribution of the buccinid gastropod *Brachysphingus* from uppermost Cretaceous and Lower Cenozoic marine strata of the Pacific slope of North America. *Journal of Paleontology* 71: 847–861.
- Squires, R. L. 2003. Turnovers in marine gastropod faunas during the Eocene-Oligocene transition, west coast of the United States. In: D. R. Prothero, L. C. Ivany and E. A. Nesbitt (eds.) *From Greenhouse to Icehouse: The Marine Eocene-Oligocene Transition*. New York, Columbia University Press, pp. 14–35.
- Squires, R. L. and G. L. Kennedy. 1998. Additions to the late Paleocene molluscan fauna from the Santa Monica Mountains, Los Angeles County, southern California. *The Veliger* 41: 157–171.
- Squires, R. L. and L. R. Saul. 1998. New upper Paleocene species of the bivalve *Plicatula* from southern California. *Journal of Paleontology* 72: 1024–1029.
- Squires, R. L. and L. R. Saul. 2001. A new genus of aporrhaid gastropod from upper Paleocene rocks in southern California. *The Veliger* 44: 327–330.
- Squires, R. L. and L. R. Saul. 2006. Additions and refinements to Aptian to Santonian (Cretaceous) *Turritella* (Mollusca: Gastropoda) from the Pacific slope of North America. *The Veliger* 48: 46–60.
- Stanton, T. W. 1896. The faunal relations of the Eocene and Upper Cretaceous on the Pacific coast. U. S. Geological Survey, Annual Report 17, pt. 1: 1009–1048.
- Stenzel, H. B. and F. E. Turner. 1940. Turritellidae from the Paleocene and Eocene of the Gulf Coast. University of Texas Publication 3945: 831–844.
- Stenzel, H. B. and F. E. Turner. 1942. Eocene and Paleocene Gastropoda *Mesalia*. In: *Type invertebrate fossils of North America*. Bureau of Economic Geology, Austin, Texas, cards 109–121.
- Stewart, R. B. 1927. Gabb's California fossil type gastropods. *Proceedings of The Academy of Natural Sciences of Philadelphia* 78: 287–447.
- Stilwell, J. D., W. J. Zinsmeister, and A. E. Oleinik. 2004. Early Paleocene mollusks of Antarctica: Systematics, paleoecology and paleobiogeographic significance. *Bulletins of American Paleontology* 367: 1–89.
- Stoliczka, F. 1868. Cretaceous fauna of southern India. Volume 2. The Gastropoda. *Memoirs of the Geological Survey of India, Palaeontologia Indica*, 204 pp.
- Strathearn, G. E., K. Griffis and B. L. Ingram. 1988. Palynomorphs and benthic foraminifera from a portion of the Coal Canyon Formation (Paleocene-Eocene). In: M. V. Filewicz and R. L. Squires (eds.) *Paleogene Stratigraphy, West Coast of North America*. Pacific Section, SEPM, Book 58, pp. 73–82.
- Sundaram, R., R. A. Henderson, K. Ayyasami, and J. D. Stilwell. 2001. A lithostratigraphic revision and palaeoenvironmental assessment of the Cretaceous System exposed in the onshore Cauvery basin, southern India. *Cretaceous Research* 22: 743–762.
- Tantawy, A. A., G. Keller, T. Adatte, W. Stinnesbeck, A. Kassab, and P. Schulte. 2001. Maastrichtian to Paleocene depositional environment of the Dakhla Formation, Western Desert, Egypt: Sedimentology, mineralogy, and integrated micro- and macrofossil biostratigraphies. *Cretaceous Research* 22: 795–827.
- Thiele, J. 1929–1935. *Handbuch der systematischen Weichtierkunde*. Gustav Fischer, Jena, 1154 pp.
- Waring, C. A. 1914. Eocene horizons of California. *Journal of Geology* 22(8): 782–785.
- Waring, C. A. 1915. Fossils characteristic of California formations. In: R. P. McLaughlin and C. A. Waring, *Geologic Oil Field Maps and Drawings. Map Folio accompanying California State Mining Bureau Bulletin* 69.
- Waring, C. A. 1917. Stratigraphic and faunal relations of the Martinez to the Chico and Tejon of southern California. *Proceedings of the California Academy of Sciences, 4th Series*, 7(4): 41–124.
- Weaver, C. E. 1953. Eocene and Paleocene deposits at Martinez, California. University of Washington Publications in Geology 7: 1–102.
- Wenz, W. 1938–1944. *Gastropoda. Teil 1: Allgemeiner Teil und Prosobranchia*. In: O. H. Schindewolf (ed.) *Handbuch der Paläozoologie, Band 6*. Gebrüder Borntraeger, Berlin: 1639 pp. [Reprinted 1960–1961].
- Whidden, K. J., D. J. Bottjer, S. P. Lund and W. V. Sliter. 1995. Paleogeographic implications of Paleogene shallow-water limestones in the southern San Rafael Mountains, California. In: A. E. Fritsche (ed.) *Cenozoic Paleogeography of the Western United States—II*. Pacific Section (Society for Sedimentary Geology), Book 75: 193–211.
- White, C. A. 1887. Contributions to the paleontology of Brazil; comprising descriptions of Cretaceous invertebrate fossils, mainly from the provinces of Sergipe, Pernambuco, Para and Bahia. *Archivos do Museu Nacional do Rio de Janeiro* 7: 1–273.
- Whitfield, R. P. 1891. Observations on some Cretaceous fossils from the Beyrât District of Syria, in the Collection of the American Museum of Natural History, with descriptions of some new species. *Bulletin of the American Museum of Natural History* 3(2): 381–441.

- Wiedey, L. W. 1928. Notes on the Vaqueros and Temblor formations of the California Miocene with descriptions of new species. *Transactions of the San Diego Society of Natural History* 5(10): 95–182.
- Woods, H. 1922. Mollusca from the Eocene and Miocene deposits of Peru. In: T. O. Bosworth (ed.) *Geology of the Tertiary and Quaternary periods in the north-west part of Peru*. MacMillan and Company, London, pp. 51–139.
- Zinsmeister, W. J. 1974. Paleocene biostratigraphy of the Simi Hills, Ventura County, California. University of California, Riverside, unpub. Ph. D. dissertation, xii + 236 pp.
- Zinsmeister, W. J. 1983. Late Paleocene (“Martinez Provincial Stage”) molluscan fauna from the Simi Hills, Ventura County, California. In: R. L. Squires and M. V. Filewicz (eds.) *Cenozoic Geology of the Simi Valley Area, Southern California*. Pacific Section, SEPM Fall Field Trip Volume and Guidebook, Book 35, pp. 61–70.
- Zinsmeister, W. J. and L. M. Paredes-Mejia. 1988. Paleocene biogeography of the west coast of North America: A look at the molluscan fauna from Sepultura Formation, Mesa San Carlos, Baja California Norte. In: M. V. Filewicz and R. L. Squires (eds.) *Paleogene Stratigraphy, West Coast of North America*. Pacific Section, SEPM West Coast Paleogene Symposium, Volume 58, pp. 9–22.

APPENDIX

LOCALITIES CITED

Localities are LACMIP, unless otherwise noted. All quadrangle maps are U. S. Geological Survey maps.

7060. Elevation 1427 ft., on ridge between Temesal and Santa Ynez canyons at edge of fire road on top of ridge, Topanga Canyon Quadrangle (7.5 minute, 1952, photorevised 1981), Los Angeles County, southern California. Paleocene. Santa Susana Formation. Coll.: H. D. B. Wilson, June 1, 1941.
10508. North slope of Trailer Canyon near top of ridge between Quarry and Trailer canyons at approximately 1325 ft. elevation and just west of saddle, just below coralline-algal beds in limy siltstone west of small fault, road cut north side of unpaved road 5600 ft. north of San Vicente y Santa Monica Grant boundary, 10,400 ft. east of Los Angeles City boundary, Topanga Quadrangle (7.5 minute, 1952, photorevised 1981), east of Santa Ynez Canyon, Palisades Highlands, Santa Monica Mountains, Los Angeles County, southern California. Lower upper Paleocene (lower Thanetian). Santa Susana Formation. Coll.: G. Strathearn and others, fall, 1982.
11717. Float at about 1600 ft. elevation in bottom of south-flowing gully joining Quarry Canyon at about 1410 ft. elevation; 1500 ft. SW of hill 2036, Topanga Quadrangle (7.5 minute, 1952, photorevised 1981), Los Angeles County, southern California. Paleocene. Santa Susana Formation. Coll.: J. M. Alderson, November 11, 1980.
21581. Black nodular shale and conglomerate on road 1.1 mi. east from Cienaga Camp at Fish Canyon forks toward Warm Springs summit; on northwest side of ravine; north side East Fork Fish Canyon, T. 6 N, R. 16 W, approximately 2050 ft. north, 750 ft. east of bench mark 2205, Warm Springs Mountain Quadrangle (7.5 minute, 1958, photorevised 1974), Los Angeles County, southern California. Paleocene (upper Danian). San Francisquito Formation. Coll.: R. W. Webb and E. H. Quayle, June 23–24, 1941.
21607. South 1/2, SE 1/4, section 25, T. 2 N, R. 18 W, Calabasas Quadrangle (7.5 minute, 1952, photorevised 1967), Ventura County, southern California. Lower upper Paleocene (lower Thanetian). Santa Susana Formation. Coll.: Kinney and Sherman, date unknown.
21554. Reworked fossil boulders in conglomerate, in second spur canyon off Poison Oak Canyon east of Las Lajas Canyon, 2800 ft. up canyon (north) from Poison Oak Canyon; on west slope 25 ft. above bottom of canyon, Santa Susana Quadrangle (7.5 minute, 1951, photorevised 1969), north side Simi Valley, Ventura County, southern California. Paleocene. Santa Susana Formation. Coll.: P. L. Goldman, date unknown.
22330. Beds cropping out on nose of spur on west side of Meier Canyon, approximately 600 ft. north of second “n” in “Meier Canyon,” Santa Susana Quadrangle (7.5 minute, 1951, photorevised 1969), south side of Simi Valley, Simi Hills, Ventura County, southern California. Lower middle Paleocene (Selandian) = *Turritella peninsularis* Zone. Santa Susana Formation, “Martinez marine member.” Coll.: W. P. Popenoe, April 3, 1946.
22557. Sandstone bed below small waterfall [dry] west of road going south through Barclay Ranch, 10,162 ft. south and 5660 ft. west of junction of Southern Pacific railroad and Los Angeles Ave. about 0.25 mi. east of Santa Susana, Santa Susana Quadrangle (7.5 minute, 1951, photorevised 1969), Simi Hills, Ventura County, southern California. Paleocene. Santa Susana Formation. Coll.: M. Murphy, spring, 1950.
22698. On first large ridge; trending southwest to west of ridge trending south of hill 2150. Bearing from the northwest corner of the Calabasas Quadrangle is S14°E; distance 12,210 ft., Calabasas Quadrangle (7.5 minute, 1952, photorevised 1967), Simi Hills, Ventura County, southern California. Paleocene. Santa Susana Formation. Coll.: J. H. Fantozzi, June 1, 1951.
25281. Sandstone at elevation of 1000 ft., about 400 ft. south and 1000 ft. west of northeast corner of section 5, T. 1 S, R. 17 W, Malibu Beach Quadrangle (7.5 minute, 1950, photorevised 1967), on west side of northern tributary to Stokes Canyon, western Santa Monica Mountains, Los Angeles County, southern California. Reworked Paleocene (Selandian) fossils in middle Miocene Calabasas Formation, Stokes Canyon Breccia Member. Coll.: J. Stark and T. Susuki family, May 5, 1965.
26897. Gully west side of Temesal Canyon opposite 2nd ‘e’ of Temesal at about 1475 ft. elevation; approximately 1082 m (3550 ft.) south; 533m (1750 ft.) east of hill 22036; San Vincente and Santa Monica Grant, Topanga Quadrangle (7.5 minute, 1952, photorevised 1967), Santa Monica Mountains, Los Angeles County, southern California. Middle upper Paleocene (middle Thanetian). Santa Susana Formation. Coll.: J. M. Alderson, March 9, 1980.
- UCMP 1540. Elevation 1000 ft., 1 mi. south of Stewartville (site), northeast corner of NW 1/4, section 15, T. 1 N, R. 1 E, Antioch South Quadrangle (7.5 minute, 1973, photorevised), 300 ft. south of basal Tejon conglomerate and 600 ft. north of Chico-Martinez contact, northeast side of Mount Diablo, Contra Costa County, northern California. Upper middle Paleocene (Selandian) = *Turritella infragranulata pachecoensis* Zone. “Martinez” Formation, lower member. Coll.: R. E. Dickerson, circa 1912.