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THE PSEUDOMELANIID GASTROPOD *PAOSIA* FROM THE MARINE CRETACEOUS OF THE PACIFIC SLOPE OF NORTH AMERICA AND A REVIEW OF THE AGE AND PALEOBIOGEOGRAPHY OF THE GENUS

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ABSTRACT—The Pacific Slope of North America's paleontologic record of *Paosia*, a nearshore-marine, pseudomelaniid gastropod primarily associated with the Old World Cretaceous Tethyan realm, is established for the first time. Former workers have almost universally referred to this genus by its junior synonym name *Trajanella* Popovici-Hatzeg, 1899. Six species, including *Paosia pentzensis* new species, are recognized, and all are from siliciclastic facies. Their documentable geologic range is late early Albian to early Campanian. Four of the five previously named species were misallocated to genus *Acteonina* and one was placed in genus "*Trajanella*."

Paosia originated in western Europe and in the Caucasus Mountains region during the latest Jurassic (Tithonian). It arrived in the study area, possibly in the Aptian, but certainly by the late early Albian and, most likely, by way of Japan and the north Pacific gyre. Worldwide, the genus had its peak diversity during the Albian and Cenomanian. The only other Western Hemisphere records of *Paosia* are a species from the Campanian of Jamaica and a possible species from the Coniacian of Texas. *Paosia* had a preference for tropical waters, but its presence in the study area indicates that it could live in temperate-tropical transition areas.

Most of the Pacific Slope of North America species are represented by a few specimens, but when plentiful, they display variability in overall shape between juvenile and adults, with the last whorl of the adults becoming more cylindrical with growth.

Paosia kollmannii new name is proposed for the homonym *Trajanella acuminata* Kollmann, 1979.

INTRODUCTION

The pseudomelaniid gastropod *Paosia* Böhm, 1895 is an extinct genus long recognized (Böhm, 1895; Cossmann, 1907) as primarily associated with the Old World Cretaceous Tethyan realm. *Paosia* is synonymous with *Trajanella* Popovici-Hatzeg, 1899, a junior synonym name that has been used, in lieu of *Paosia*, by nearly every worker who has dealt with this gastropod.

Few workers have studied *Paosia*. Delpey (1938) and Pchelintsev (1951, 1953) focused on "*Trajanella*" species from the Mediterranean area and the Caucasus Mountains, respectively. Sohl (1987) and Kollmann (1992) provided brief, but very useful, overviews of "*Trajanella*" in their analyses of Cretaceous Tethyan gastropod faunas. Recorded "*Trajanella*" occurrences in the New World comprise a species in Jamaica (Sohl, 1967, 1987), a possible one in Texas (Nagao, 1934), and "*Trajanella*" *acuminata* Anderson, 1958 in California.

The record of *Paosia* in the region extending from Vancouver Island, British Columbia, southward to Baja California, Mexico, has been obscured by misallocation of several species to the opisthobranch *Acteonina* d'Orbigny, 1850. This concept of *Acteonina* stemmed from Gabb (1864), who named *Acteonina californica* and ?*Acteonina pupoides*. Stewart (1927) replaced the latter name with "*Acteonina*" *calafia*, and Anderson (1958) named the following seven species: *A. colusaensis*, *A. roguensis*, *A. bellavistana*, *A. berryessensis*, *A. yrekensis*, *A. ursula*, and *A. ursulagorda*. The record of *Paosia* in this region has been further obscured by overnaming as a result of not recognizing that this gastropod has considerable ontogenetic variability. *Paosia californica* (Anderson, 1958) and *Paosia ursula* (Anderson, 1958) are represented by sufficiently large collections of individuals to demonstrate that the last whorl of the adult specimens of these species becomes more cylindrical with growth.

Six species of *Paosia*, including *Paosia pentzensis* n. sp., are recognized herein from the Pacific Slope of North America. Reliable stratigraphic and geologic age data are available for the Turonian and Coniacian species. Uncertainties still exist, however, for the geologic ages of the pre-Turonian species, except for *P. acuminata* (Anderson, 1958), partly because of inexact locality information and also because of redeposition of some material. The entire age range of *P. calafia* (Stewart, 1927) is uncertain because of inexact locality information. The upper limit of the geologic age of *P. pentzensis* n. sp. is uncertain because of preservational problems.

The objectives of this paper are to integrate new morphologic information into the descriptions of the Pacific Slope *Paosia* species, more completely illustrate them, update their stratigraphic occurrences, refine their geologic ages, name and describe the new species, and integrate all of this information into a review of the age and biogeography of the genus. This paper establishes a documentable paleontologic record from late early Albian to early Campanian for this genus on the Pacific Slope of North America.

The classification system for suprafamilial taxa follows that of Ponder and Warén (1988). Morphological terms used here are defined by Cox (1960). Abbreviations used for catalog and locality numbers are: ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences, San Francisco; CIT, California Institute of Technology, Pasadena [collections now housed at LACMIP]; GSC, Geological Survey of Canada, Vancouver; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; RBCM, Royal British Columbia Museum, Victoria; UCLA, University of California, Los Angeles [collections now housed at LACMIP]; UCMP, University of California Museum of Paleontology (Berkeley); USGS, United States Geological Survey (Menlo Park, California) [collections now housed at UCMP]; USNM, United States National Museum, Washington, D.C.; VIPM, Vancouver Island Paleontological Museum at Qualicum Beach, British Columbia.

STRATIGRAPHY

The geologic ages and depositional environments of most of the formations and members cited in this paper have been summarized in recent papers by Squires and Saul (1997, 2001, 2003a, 2003b) and Saul and Squires (2003). Stratigraphic information mentioned below concerns either those rock units not discussed in recent literature or additional pertinent biostratigraphic details. These stratigraphic units are listed from oldest to youngest.

Most of the *Paosia* specimens found in the study area were collected from nearshore sandstone deposits, with some collected

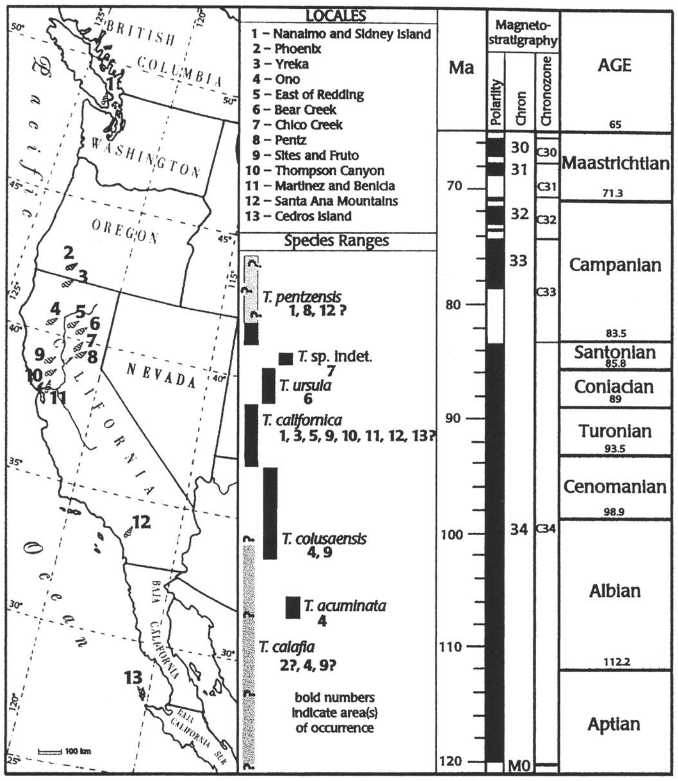


FIGURE *1*—Locality map and chronostratigraphic positions of the Pacific Slope of North America species of *Paosia* Böhm, 1895. Geologic ages and magnetostratigraphy after Gradstein et al. (1994).

from slightly deeper water sandy siltstone deposits. Both types of deposits broadly reflect inner-shelf environments with assemblages usually rich in mollusks indicative of normal-marine salinities. These types of environments are consistent with reports by Kollmann (1992), who suggested that "*Trajanella*" inhabited level-bottom communities below wave base. Kase (1984), however, inferred that some "*Trajanella*" lived on a rocky bottom. As will be mentioned below, specimens found along the west side of the Sacramento Valley of northern California were usually redeposited in submarine slumps (turbidites), but these are the exception.

Budden Canyon Formation.—It crops out in the Bald Hills area, near Ono, Shasta County, northern California (Fig. 1, locale 4), and consists of numerous members deposited during the Hauterivian to Turonian stages (Murphy et al., 1969). Members pertinent to this present study are the Chickabally Mudstone and Bald Hills members. The upper part of the former member is revelant to *Paosia acuminata*, whose type locality is at Texas Springs, where Cretaceous megafossils found there were assigned by Rodda (1959) to the ammonite *Brewericeras hulenense* zone, which Jones et al. (1965) correlated to the upper lower Albian.

The Bald Hills Member, which overlies the Chickabally Mudstone Member, is revelant to *Paosia colusaensis* (Anderson, 1958). Murphy et al. (1969) reported that, based on ammonites, this member ranges from upper Albian to Cenomanian.

Gabb (1864, p. 114) reported the type locality of *P. calafia* to be "on the North Fork of Cottonwood Creek, Shasta County." This locality information is very inexact, as the strata along the North Fork of Cottonwood Creek are represented by all the members of the Budden Canyon Formation and collectively range from Hauterivian to Turonian (Murphy et al., 1969). Gabb (1869, p. 173), however, reported the type locality of this species to be from the "Shasta Group, Cottonwood Creek," which is slightly more restrictive, but still very inexact as it includes strata ranging from Hauterivian to Albian. It is not likely, however, that this species is from either the Hauterivian or the Barremian parts of the formation, because, according to Murphy et al. (1969), fossil are rare in the former part and no identifiable ones have been found in the latter part. Anderson (1938, p. 136) reiterated Gabb's (1869) occurrence of this species, but Anderson (1958, p. 158) inferred *P. calafia* to be Albian or Cenomanian. It is important to mention that Rodda (1959) reported that Anderson (1938) misidentified juvenile specimens of the upper lower Albian ammonite *Brewericeras hulenense* (Anderson, 1938) as the upper Albian *Beaudanticeras haydeni* (Gabb, 1864) (see Matsumoto, 1960, p. 24, 30). Anderson's (1958) suggestion that *P. calafia* specimens were from the base of the Upper Cretaceous, therefore, is without documentation. Until better information becomes available, the geologic range of *P. calafia* can only be stated as somewhere in the Aptian to Albian (Fig. 1).

Cretaceous rocks near sites.—Anderson (1958) reported that the holotype of *P. colusaensis* (Anderson, 1958) was found in the vicinity of the "Peterson Ranch," at CAS locality 1291, near Sites, which is on the western side of Sacramento Valley in northern California (Fig. 1, locale 9). As curator at CAS, Anderson ascribed to this locality donated specimens collected from several localities in the general area. Saul (1978, p. 38–39) noted that CAS locality 1291 is the type locality of several megafossil species of different geologic ages. It is likely that these specimens are from either the Antelope Shale or the overlying Venado Sandstone Member of the informal Cortina Formation. Both the Antelope Shale and the Venado Sandstone Member are dominantly turbiditic and the basal part of the Venado contains lenses of submarine-slump deposits (Ghosh and Lowe, 1993). The Antelope Shale is largely Cenomanian in age but includes strata of late Albian age at its base. The Venado Sandstone Member is of early Turonian age and it contains reworked fossils of late Albian in age (Matsumoto, 1960, p. 34–35; Popenoe et al., 1960, chart 10e).

P. colusaensis has a range of late Albian to Cenomanian in the Bald Hills Member of the Budden Canyon Formation near Ono. This age range suggests that the holotype of *T. colusaensis* from "Peterson Ranch" near Sites is either a reworked fossil of late Albian age and, thus, found in the submarine-slump deposits, or it was found in lower Cenomanian beds in the Antelope Shale.

Lowe's (1972) mention of "*Trajanella*" *californica* from reworked late Albian fauna in the Sites area is probably a misidentification of *P. colusaensis*, as all confirmed occurrences of *P. californica* are late Cenomanian to Turonian. Furthermore, Brown and Rich (1960, 1961), who made paleontological collections from the various stratigraphic units in this area, found only specimens of "*Trajanella*" *californica* from the upper part of the Antelope Shale at USGS localities M-176 and M-177 in beds containing the Cenomanian *Turritella petersoni* Merriam, 1941.

Hornbrook Formation near Phoenix, Oregon.—Anderson (1958) reported the holotype of *Acteonina roguensis*, which we consider to be a junior synonym of *P. californica*, to be from CAS locality 445 at the "Forty-nine mine" 3.2 km south of Phoenix, Jackson County, southwestern Oregon (Fig. 1, locale 2). The Phoenix area was a site for placer mining and many of the fossils found there were collected in outwash resulting from the mining process. Cretaceous outcrops in this area that yield abundant megafossils belong to the Osburger Gulch Member of the Hornbrook Formation. This member is a time-transgressive unit younging to the south. It ranges in age from middle Albian in the Grave Creek area of Oregon to early Coniacian south of Yreka, Siskiyou, California (Fig. 1, locale 3), and in the area just south of Phoenix, the member is Turonian (Nilsen, 1993). In addition, this is low-relief country with low-dipping beds. Ranchers have canals for water, and during the construction of these canals, workmen probably redistributed the fossils. Because of these problems associated with collecting, Matsumoto (1960, p. 77), working from ammonite collections, assigned two different ages (late Cenomanian and Turonian) for rocks at this locality. He questioned whether the Cenomanian ammonite *Calycoceras* Hyatt, 1900 was from the same locality as the Turonian ones. Considering that all the other ammonites from this locality are Turonian, the holotype of *A. roguensis* is considered to be most probably Turonian.

Yolo Formation.—It crops along Putah Creek and Thompson Canyon near Monticello Dam and Lake Berryessa in western Yolo County, northern California (Fig. 1, locale 10). Popenoe et al. (1960, p. 1525), on the basis of ammonites, assigned this formation to the Turonian.

Morro Redondo Formation.—It crops out in exposures of very limited areal extent on Cedros Island, off the west coast of Baja California, Mexico (Fig. 1, locale 13). Based on gastropods, bivalves, and planktonic foraminifera, Kilmer (1984) assigned this formation to the Turonian.

Guinda Sandstone Member of Rumsey Formation.—Three partial specimens of *Paosia californica* were collected from UCMP locality A-4856 in this member near Fruto, on the west side of Sacramento Valley in northern California (Fig. 1, locale 9). These specimens, which represent reworked material, are of Turonian age, on the basis of the Turonian bivalve *Cucullaea melhaseana* Anderson, 1958 found associated with them.

Nanaimo Group.—Two formations in the Nanaimo Group along the eastern side of Vancouver Island, British Columbia (Fig. 1, locale 1), have yielded specimens of *Paosia*. An unnamed formation that crops out on Sidney Island northeast of Victoria and west of San Juan Island (Haggart, 1991a) is of Turonian age (Popenoe et al., 1987; Haggart, 1991b) and contains *Paosia californica*. The Haslam Formation that crops out near Nanaimo is of late Santonian to earliest Campanian age, based on ammonites (Haggart, 1991a).

Williams Formation.—It crops out along the western flank of the Santa Ana Mountains, Orange County, southern California (Fig. 1, locale 12), and consists of the Schulz and the Pleasants Sandstone members. A specimen of *Paosia pentzensis* n. sp. was collected from LACMIP locality 27199. This locality equals locality F38 of Schoellhamer's et al. (1981), which is plotted, on their geologic map, in the basal part of the Schulz Member. Popenoe (personal commun.) believed that the fossils at this locality represent reworked material from the underlying upper part of the Holz Shale Member, and we concur. Although fossils in the upper Holz Shale and the Schulz Member were reported by Saul (1982, fig. 3) as being of middle Campanian age, this age assignment must be adjusted to late early Campanian because of revisions in the Late Cretaceous time scale by Gradstein et al. (1994).

Poorly preserved specimens of *P. pentzensis*? occur in the Pleasants Sandstone Member, which contains the ammonite *Metaplacenticeras pacificum* (Smith, 1900), indicative of the late middle Campanian to early late Campanian (Elder and Saul, 1996).

PALEOBIOGEOGRAPHY OF *PAOSIA*

The geologic occurrences of *Paosia* that we are aware of are listed in Table 1 and summarized graphically in Figure 2. References heavily utilized in our study were Nagao (1934), Delpey (1938), Pchelintsev (1951, 1953), Sohl (1971, 1987), and Kollmann (1992). These works focus mainly on Old World *Paosia* species. Sohl (1971, 1987) and Kollmann (1992) were the only ones of these workers to include any mention of "*Trajanella*" from California.

Paosia has been variously reported as ranging from Cenomanian to Late Cretaceous (Cossmann, 1909), Aptian to Late Cretaceous (Wenz, 1938), Albian to Late Cretaceous (Delpey, 1938), and Barremian to the end of the Maastrichtian (Sohl, 1987). Pchelintsev (1951, 1953, 1963), furthermore, reported the range to be Tithonian (latest Jurassic) to Santonian. Pchelintsev's Tithonian record is based on "*Trajanella*" *vera* Pchelintsev, 1927 from the Caucasus Mountains. To this Tithonian record, we add *Poasia amygdaloides* (Zittel, 1873; Wenz, 1938, p. 375, fig. 891 [as *Oonia amygdaloides* Zittel, 1873, an example of *Oonia* Gemmellaro, 1878]; Pchelintsev et al., 1960, pl. 16, figs. 9a, 9b [as *O. amygdaloides*, an example of *Oonia*]) from uppermost Tithonian (=Portlandian) strata in the Moravia area of the Czech Republic. Zittel's species is known from well preserved specimens that show the cylindrical last whorl, compressed spire, and prominently sinuous growth lines that are diagnostic of *Paosia*. It is unfortunate that Wenz (1938) used Zittel's species as a representative example of *Oonia*, rather than illustrating its type species, *Melania abbreviata* Terquem, 1855 [=*Oonia hettangiensis* Cossmann, 1909], from the Lower Jurassic (Hettangian). There are at least four homonyms of *Melania abbreviata* and Cossmann (1909, p. 86) listed them.

Crimea and southeastern France are the only known Neocomian occurrences of *Paosia* (Cossmann, 1907; Pchelintsev, 1931, 1963). The first moderately widespread species is "*Trajanella*" *fraasi* (Dietrich, 1914), of late Aptian to early Albian age in Honshu, Japan, and of Aptian age in Tanganyika, Africa (Kase, 1984). Other Aptian species are known from the vicinity of the Caucasus Mountains, southeastern France, and northeastern Spain (Pchelintsev, 1927; Delpey, 1942; Calzada, 1989).

During the Albian, *Paosia* was present not only in western Europe (Delpey, 1942; Kollmann, 1979), Crimea and the Caucasus Mountains (Pchelintsev, 1927), but also on the east coast of the Suez Canal (Douvillé, 1916), Madagascar (Delpey, 1949), and northern California. The first documentable record of *Paosia* on the Pacific Slope of North America is late early Albian *P. acuminata* in northern California. Its arrival coincided with both a global trend of rising sea level (Haq et al., 1987) and with warm and equable surface waters (Frakes, 1999). A likely dispersal route would have been by way of the easternmost Tethys (Japan) and the northern Pacific gyre. The evidence is that all the early occurrences (Albian and Cenomanian) of *Paosia* in North America are in southern Oregon and northern California. Earlier southward occurrences are lacking in Baja California, the mainland of Mexico, the Gulf Coast of the United States, and northern South America. In particular, *Paosia* is not present in the upper Aptian Alisitos Formation in Baja California, which has a Tethyan gastropod- and bivalve-rich fauna (Allison, 1955, 1974). If *Paosia* had arrived onto the Pacific Slope of North America via an equatorial route connected to the western Tethys, there should be some record of it in these low-latitude locales. This late early Albian occurrence, followed by the northern California occurrence of *P. colusaensis* in the late Albian, corroborates Saul's (1986) suggestion that there is a strong Tethyan component to the Albian faunas of the Pacific slope of North America.

Sohl (1987) reported "*Trajanella*" from the Albian of Angola, Africa. He cited no species, but it is very likely that he based this record on Darteville and Brebion's (1956, p. 41, pl. 3, figs. 4a, 4b) illustrations of *Pterodonta inflata* d'Orbigny (1842), which vaguely resembles a *Paosia*. The high spire with convex whorls, very swollen last whorl, and columellar callus, however, are like features found on the naticiform *Tylostoma* Sharpe, 1849.

During the Cenomanian, *Paosia* continued to be present in western Europe (Geinitz, 1874; Böhm, 1895; Popovici-Hatzeg, 1899; Rahman, 1967), the Caucasus Mountains (Pchelintsev,

TABLE 1—Stage and geographic distribution of species of *Paosia*.

Stage	Species	Location
Tithonian	*P. amygdaloides* (Zittel, 1873)	Czech Republic
	P. vera (Pchelinstev, 1927)	Caucasus Mountains
Valanginian	*P. alsusensis* (Pchelintsev, 1931)	Crimea
Barremian	*P. allardi* (Cossmann, 1907)	Southeastern France
	P. capduri (Cossmann, 1907)	Southeastern France
	P. glabra (Pchelintsev, 1931)	Crimea
	P. konobensis (Pchelintsev, 1963)	Crimea
Aptian	*P. angusta* (Pchelintsev, 1927)	Caucasus Mountains
	Possibly *P. calafia* (Stewart, 1927)	Northern California
	P. clansayesiensis (Delpey, 1942)	Southeastern France
	P. conoidea (Pchelintsev, 1927)	Caucasus Mountains
	P. cristobaldi (Verneuil and Lorière, 1868)	Northeastern Spain
	P. fraasi (Dietrich, 1914) [= *P. japonica* (Nagao, 1934)]	Tanzania, Africa; Honshu, Japan
Albian	*P. acuminata* (Anderson, 1958)	Northern California
	P. boulei (Collignon, 1933)	Madagascar
	P. brevispira (Douvillé, 1916)	Egypt (Suez Canal)
	Possibly *P. calafia* (Stewart, 1927)	Northern California
	P. colusaensis (Anderson, 1958)	Northern California
	P. fraasi (Dietrich, 1914)	Honshu, Japan
	P. pontica (Pchelintsev, 1927)	Caucasus Mountains
	P. komarensis (Pchelintsev, 1927)	Caucasus Mountains
	P. kollmanni new name	Austria
Cenomanian	*P. colusaensis* (Anderson, 1958)	Northern California
	P. faldaltensis (Böhm, 1895)	Northern Italy
	P. munieri (Popovici-Hatzeg, 1899)	Romania
	P. ornata (Pchelintsev, 1951)	Caucasus Mountains
	P. romani (de Brun and Chatelet, 1926)	Southeastern France
	P. rovikensis (Djalilov, 1977)	Tajikistan
	P. subamphora (Pchelintsev, 1951)	Caucasus Mountains
	P. stoliczkai (Geinitz, 1874) [= *P. laubeana* (Geinitz, 1874) and *P. paosi* (Böhm, 1895)]	Germany and Czech Republic
Turonian	*P. amphora* (d'Orbigny, 1842)	France
	P. californica (Gabb, 1864)	British Columbia to southern California and possibly Cedros Is., Baja California
	P. gigantea (Stoliczka, 1868)	Southern India; Lebanon
	P. godoganiensis (Pchelintsev, 1951)	Caucasus Mountains
	P. zitteli (Delpey, 1938)	Italy
Coniacian	*P. kieslingswaldensis* (Weinzettl, 1910)	Poland
	P. ursula (Anderson, 1958)	Northern California
	P.? texana (Roemer, 1852)	Central Texas
Santonian	*P. dutoiti* (Rennie, 1930)	Pondoland, South Africa
	P. jacobi (Delpey, 1938)	France
	P. pentzensis n. sp.	British Columbia to southern California
	P. subgigantea (Pchelinstev, 1951)	Caucasus Mountains
Campanian	*P. dutoiti* (Rennie, 1930)	Pondoland, South Africa
	P. pentzensis n. sp.	British Columbia to southern California
	P. sp. Sohl, 1967, 1987	NW Jamaica

1951, 1953), southwestern Oregon, and northern California. Occurrences in the latter two locales are rare. It also spread to Tajikistan (Djalilov, 1977).

Although Sohl (1987) reported that "*Trajanella*" reached its maximum diversity in Turonian time, our review of the available literature on worldwide occurrences of *Paosia* shows that its maximum diversity was reached during the Albian to Cenomanian. It must be pointed out, however, that it is difficult to determine the stages of some occurrences of *Paosia* because of imprecise stratigraphy and age dating. *Paosia* apparently reached its peak diversity (three species) on the Pacific slope of North America during the Albian, but the age of the type locality of *P. calafia* is poorly constrained.

During the Turonian, *Paosia* was still present in western Europe (Delpey, 1938), the Caucasus Mountains (Pchelintsev, 1951, 1953), and in northern California. It also occurred, for the first time, in Lebanon (Delpey, 1940), southern India (Stoliczka, 1868), southwestern Oregon, southern California, and southern British Columbia. Only a single Pacific Slope of North America Turonian species, *P. californica*, is known, but it was the most common and widespread of any species of *Paosia* from this area. It is found in the Nanaimo basin of Vancouver Island in southern British Columbia to southern California, and possibly to Cedros Island, Baja California, Mexico.

Stoliczka (1868) reported "*Trajanella*" *gigantea* (Stoliczka, 1868, p. 289–290, pl. 21, figs. 3–5 [as *Euchrysalis* Laube, 1866]) from three localities in the Arrialoor group [Ariyalur Group] in the Cauvery Basin in southern India, and the age of the marine part of this group is Santonian to middle Maastrichtian (Acharyya and Lahiri, 1991; Govinidan et al., 1996; Tewari et al., 1996; Sundaram et al., 2001). Stoliczka's three localities are Anaipadi [Anapaudy], Alundanapooram [Alundalippur], and Comarapolliam. According to the maps and modern lithostratigraphic classification and geological information found in Sundaram et al. (2001), however, two of these localities plot in the Trichonopoly Group rocks that underlie the Ariyalur Group. Specifically, the Anaipadi locality plots in the Turonian, upper part of the Kulakkalnattam Formation, and the Alundanapooram locality plots in the lower Turonian, lower part of this formation. Although Bandel (2000) reported on newly collected gastropods from the Trichnopoly Group, "*Trajanella*" was not found by him. The Comarapolliam locality could not be found on any map available to us, but probably it too would plot in Turonian rocks.

We know of only three Coniacian occurrences of *Paosia*. One

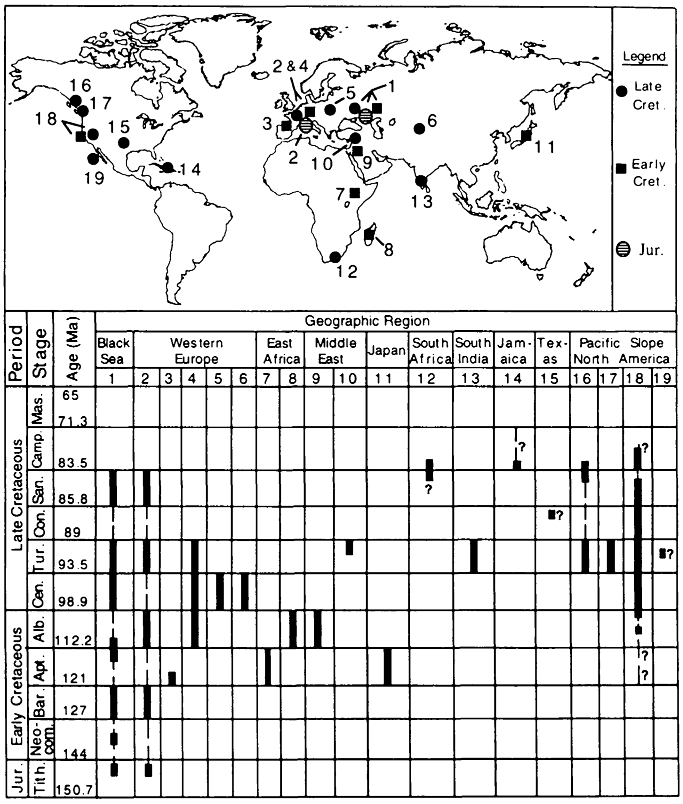


FIGURE 2—Global chronostratigraphic and geographic distribution of *Paosia*. Dashed vertical lines indicate presumed occurrence. 1 = "Black Sea area" = Crimea and Caucasus Mountains; 2 = southeastern France; 3 = northeastern Spain; 4 = Austria, Germany, Czech Republic, and northern Italy; 5 = Romania; 6 = Tajikistan; 7 = Tanzania; 8 = Madagascar; 9 = Suez Canal and Egypt; 10 = Lebanon; 11 = northern Honshu; 12 = Pondoland; 13 = Cauvery Basin; 14 = northwestern Jamaica; 15 = central Texas; 16 = south end of Vancouver Island, British Columbia; 17 = southwest Oregon; 18 = California; and 19 = Cedros Island.

is *P. kieslingswaldensis* (Weinzettl, 1910) from Poland (H. A. Kollmann, personal commun.). The second is *P. ursula* from northern California, and the other is a possible species from Texas. Unfortunately, the basis of this latter record, a single specimen from the Austin Chalk of Comal County, central Texas, is missing its anterior end. This specimen, originally described as *Eulima*? *texana* Roemer (1852, p. 40, pl. 4, fig. 2), strongly resembles a "*Trajanella*," as noted by Nagao (1934, p. 241). We concur with Nagao's assessment and questionably assign the species to *Paosia*. Akers and Akers (1997, p. 167, fig. 163), who retained the *E.*? *texana* identification, also illustrated this specimen, summarized its salient morphologic features, and updated its stratigraphic occurrence.

Santonian occurrences of *Paosia* are limited to the Caucasus Mountains (Pchelintsev, 1951, 1953), France (Delpey, 1938), South Africa (Rennie, 1930), and *P.* sp. indet. from northern California. In addition, *P. pentzensis* n. sp. is known from upper Santonian to lowermost Campanian strata in the Nanaimo Group on the east coast of Vancouver Island, British Columbia.

The occurrence of *P. pentzensis* n. sp. in the Nanaimo Group on Vancouver Island, British Columbia, is the farthest north (48°N) of any species of *Paosia*, but this occurrence must be corrected for post-Late Cretaceous tectonic transport. Ward et al. (1997) reported that, on the basis of paleomagnetic studies, the Nanaimo Group has undergone about 3500 km of northwardly movement from its original position near modern-day Baja California. Kodama and Ward (2001), reported, however, that, on the basis of paleomagnetic inclinations corrected for the effects of burial compaction, the Nanamio Group rocks were no farther south in the Late Cretaceous than northern California (40°N). Our study of *Paosia* helps support this latter work because most Pacific Slope populations of *Paosia* were located in northern California during the Turonian to Campanian, thus a position for Vancouver Island in close proximity to southern Oregon and northern California near these populations seems more parsimonious than a far-south location equivalent to that of modern-day Baja California.

In addition to *Paosia pentzensis* n. sp., we are aware of only two other Campanian records of *Paosia*. One is "*Trajanella*" *dutoti* Rennie (1930) from near the mouth of the Umzamba River in Pondoland, South Africa. This species is from strata reported as equivalent to the middle or upper Santonian to lower Campanian (Klinger and Kennedy, 1977). The other Campanian record of this genus is *T.* (*Paosia*) sp. Sohl (1987) from the Hanover Inlier of northwestern Jamaica. The Hanover Inlier is now referred to as the Lucea Inlier. Sohl gave no additional stratigraphic or chronostratigraphic details. This species is the same as "*Trajanella*" (*Paosia*) sp. Sohl (1967) from east of Lucea, Jamaica. The Hanover Inlier is composed of Santonian and Campanian strata (Lewis and Draper, 1990; Wiedmann and Schmidt, 1993) and Sohl's (1987) referral of his "*Trajanella*" (*Paosia*) sp. to the Campanian seems valid, but more biostratigraphic details are needed to confirm its geologic age.

Sohl (1987) reported that "*Trajanella*" ranges to the end of the Maastrichtian. He gave no detailed information, but he undoubtedly based the Maastrichtian record on "*Trajanella*" *doncieuxi* Vidal (1917, p. 11, pl. 4, figs. 3, 4), from the Lérida region of northeastern Spain. Bataller (1949, p. 78–79, fig. on p. 78) also illustrated this species. Vidal's species, which has numerous and very high spire whorls, is a *Pseudomelania* Pictet and Campiche, 1862. We know of no valid Maastrichtian records of *Paosia*.

Sohl (1987, p. 1097) reported that "*Trajanella*" occurs in Peru but cited no species. His reference was probably to *Pseudomelania simplex* Olsson (1944, p. 66–67, pl. 12, fig. 17) from Maastrichtian strata of northern Peru. The spire of this species, however, is much higher than that of *Paosia* and we do not consider Olsson's species to belong to *Paosia*.

Paosia is not known from the mainland of Mexico, South America, west Africa, Australia, or New Zealand.

Paosia has long been a gastropod dominantly indicative of tropical waters, because it had a preference for living within the circumequatorial Tethyan Realm biotic province (Sohl, 1971, 1987; Kollmann, 1992), whose approximate latitudinal limits were depicted by Sohl (1987, fig. 1). Some other organisms representative of this realm are larger foraminifera; algal-coral, coral-rudist, or rudist-dominated organic framework builders; and actaeonellid and nerineid gastropods. Sohl (1987) placed "*Trajanella*" in his "Group Two"-type of Tethyan gastropods. According to him, these originated in the Early Cretaceous, became most diverse in the mid-Cretaceous, and declined in diversity and became extinct in the Late Cretaceous. "Group Two" gastropods show a wider latitudinal distribution than some other Tethyan gastropods and range beyond the limits of the framework-building coral and rudist facies into other environments, but rarely into the temperate-tropical transition areas.

The boundaries of the Tethyan Realm varied with time but were generally broadest during the Aptian to Turonian and the narrowest during the Coniacian to Maastrichtian (Sohl, 1987). Northward and southward of the boundary of these Tethyan core areas were transitional regions where mollusks of Tethyan affinities could occur as admixtures with faunas that preferred warm-temperate conditions (Sohl, 1971, 1987). Sohl (1971, p. 1619) used the fauna from the Bald Hills Member fauna of the Budden Canyon Formation, located approximately 40 degrees north in northern California, as an example of these transitional faunas, with the Tethyan-affinity "*Trajanella*" (i.e., *Paosia acuminata*) being one of the key components of the fauna. This present paper adds many new occurrences of *Paosia* on the Pacific Slope and these occurrences range from Cenomanian to Campanian age. Most of these are between 38 degrees and 42 degrees north, in southern Oregon and northern California (Fig. 1, locales 2 to 11), and were unaffected by tectonic transport. These occurrences support Sohl's (1987) contention that "*Trajanella*" could go beyond tropical areas and live in temperate-tropical transition areas. Sohl, however, believed that these excursions of the genus into temperate-tropical waters were rare, but the Pacific Slope distribution of *Paosia* indicates that the genus's distribution was not as restricted as previously implied.

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA Linnaeus, 1758
Class GASTROPODA Cuvier, 1797
Superorder CAENOGASTROPODA Cox, 1959
Order NEOTAENIOGLOSSA Haller, 1882
Superfamily PSEUDOMELANIOIDEA Fischer, 1885
Family PSEUDOMELANIIDAE Fischer, 1885

Discussion.—Tracey et al. (1993) reported that this family is a poorly known and probably polyphyletic group of elongate, commonly rather featureless shells, and that its geologic range is late Middle Triassic to late early Miocene. Pseudomelaniid shells are anomphalous, bear sinuous growth lines, and are usually smooth with a flat-sided conical spire, a rounded body-whorl base, and a smooth inner lip without folds.

Pchelintsev (1951) introduced the family name Trajanellidae, consisting of *Paosia* Böhm (1895) and "*Trajanella*" Popovici-Hatzeg, 1899. Then, in a lengthy discussion of this family in Pchelinstev (1953), he inexplicably stated it be new therein. Tracey et al. (1993) included Trajanellidae in Pseudomelaniidae because of so few characters to distinguish between them, and we concur. Taylor and Sohl (1962) retained *Paosia* and "*Trajanella*" in the Pseudomelaniidae.

Genus PAOSIA Böhm, 1895

Type species.—*Natica fadaltensis* Böhm, 1895, by original designation; Late Cretaceous (Cenomanian), northern Italy.

Other species.—See Table 1.

Diagnosis.—Elongate-conical (juveniles more ovate); spire high or low; whorls smooth (rarely with spiral grooves) and overlapping slightly; outer lip projected and incurved anteriorly; columella smooth and usually callused; growth lines sinuous.

Description.—Shell medium to moderately large-sized (up to 95 mm height), elongate-conical with possible ontogenetic and adult variation in shape. Pleural angle commonly variable between juvenile and adult stages. Spire high or low, moderately convex or slightly concave. Whorls overlap slightly. Suture slightly to moderately impressed. Sutural slope (=angle between suture and plane perpendicular to axis) on more mature whorls increases rapidly relative to earlier whorls, resulting in suture descending rapidly relative to earlier whorls and, hence, a proportionally taller penultimate whorl than seen on earlier whorls. Last whorl of juveniles ovate to moderately globose; last whorl of adults cylindrical, slightly inflated, and elongate. Whorls smooth, rarely with very fine and closely spaced spiral grooves on spire (juveniles) and adjacent to callus band. Anomphalous. Aperture elliptical, posteriorly constricted, anteriorly rounded; base of aperture U-shaped. Outer lip projected and incurved anteriorly. Columella smooth, very rarely with one low, but distinct protuberance near anterior end on late-stage adults. Columella usually callused. Callus band commonly present, and usually with well-delineated abaxial margin. Growth lines parasigmoidal (reverse S-shaped).

Discussion.—*Eulima amphora* d'Orbigny, 1842, the type species of "*Trajanella*" Popovici-Hatzeg, 1899 (by original designation; late Turonian, France), is a *Paosia*, albeit a tall, cylindrical one, and this shape is the main basis for recognizing *Trajanella*. In this present study, within large collections of individuals, juveniles are plump and mature specimens are tall and cylindrical. Given the wide range of morphology found within species of *Paosia*, we believe that *Trajanella* is a junior synonym. Nagao (1934, p. 240) had the type species of "*Trajanella*" as "*T.*" *munieri* Popovici-Hatzeg, 1899, from the lower Cenomanian of Romania. Popovici-Hatzeg (1899, p. 9) clearly designated, however, the type species to be *E. amphora* d'Orbigny, 1842.

Wenz (1943, p. 1495–1496, fig. 4199) and Sohl (1967, 1987) used *Paosia* as a subgenus of "*Trajanella*," but they did not explain their reasons. Wenz, furthermore, indicated that *Paosia* is the same as *Alpagina* [Munier-Chalmas] Delpey, 1938. Delpey (1938) also used *Paosia* as a subgenus of "*Trajanella*." She differentiated them on the basis of a low swelling on the columella, but we believe that this is not a generic or subgeneric character. She also mentioned that *Paosia* is shorter and rounder than *Trajanella*, but she then stated that there is too much morphologic variation in *Trajanella* to make these characters reliable.

Possible variation in shell shape of *Paosia* during growth is a feature not reported by most workers. If a species of this genus is represented by plentiful specimens, including both juveniles and adults, the age-related variation should be detectable. Kase (1984), for example, reported that "*Trajanella*" *fraasi* (Dietrich, 1914), which is one of the most common gastropods from the Lower Cretaceous (upper Aptian and lower Albian) Miyako Group in Japan, shows variation in shape during growth, with coeloconoid shells in the early growth stage and cyrtoconoid shells in later growth stage. As will be discussed below, we found variation in the shell shape of the different growth stages of *Paosia californica*, *P. ursula*, and *P. pentzensis* n. sp.

Paosia is similar to the pseudomelaniid *Oonia* Gemmellaro, 1878, whose geologic range is late Middle Triassic (Ladinian) to Early Cretaceous (Barremian) (Cossmann, 1909; Wenz, 1938). *Oonia* was especially diverse during the Middle Jurassic (Bathonian) (see Morris and Lycett, 1850; Piette, 1855) and during the Late Jurassic (Kimmeridgian and Tithonian) (see Bigot, 1937; Cox, 1965). By the Early Cretaceous (Valanginian), *Oonia* was much reduced in diversity (see Choffat, 1886). The youngest species we know of is Barremian/earliest Aptian in age (see Cox, 1954). Based on comparison with Late Jurassic specimens of *Oonia* from the LACMIP collections, as well as on comparison with illustrations in the literature, *Paosia* differs from *Oonia* by having a projected and incurved anterior end of the outer lip, a maximum size that is larger, the spire whorls less elevated, slightly overlapping whorls, ontogenetic change of spire shape from low conical to elongate conical, ontogenetic change in shape of last whorl from subcylindrical to convex, and growth lines of greater sinuosity.

Various species of *Paosia* have been misassigned to somewhat similar genera. These genera are the Pennsylvanian to Late Jurassic (Zilch, 1959) acteonid *Acteonina* d'Orbigny, 1850; the Middle Triassic to Middle Jurassic (Wenz, 1938) subulitid *Euchrysalis* Laube, 1866; the Late Triassic to Cenomanian (Wenz, 1938) pseudomelaniid *Pseudomelania* Pictet and Campiche, 1862; the Eocene to Recent (Wenz, 1938) pyramidellid *Chemnitzia* d'Orbigny, 1839; and the Miocene to Recent (Wenz, 1938) phasianellid *Phasianella* Lamarck, 1804. *Paosia* differs from all of these genera by

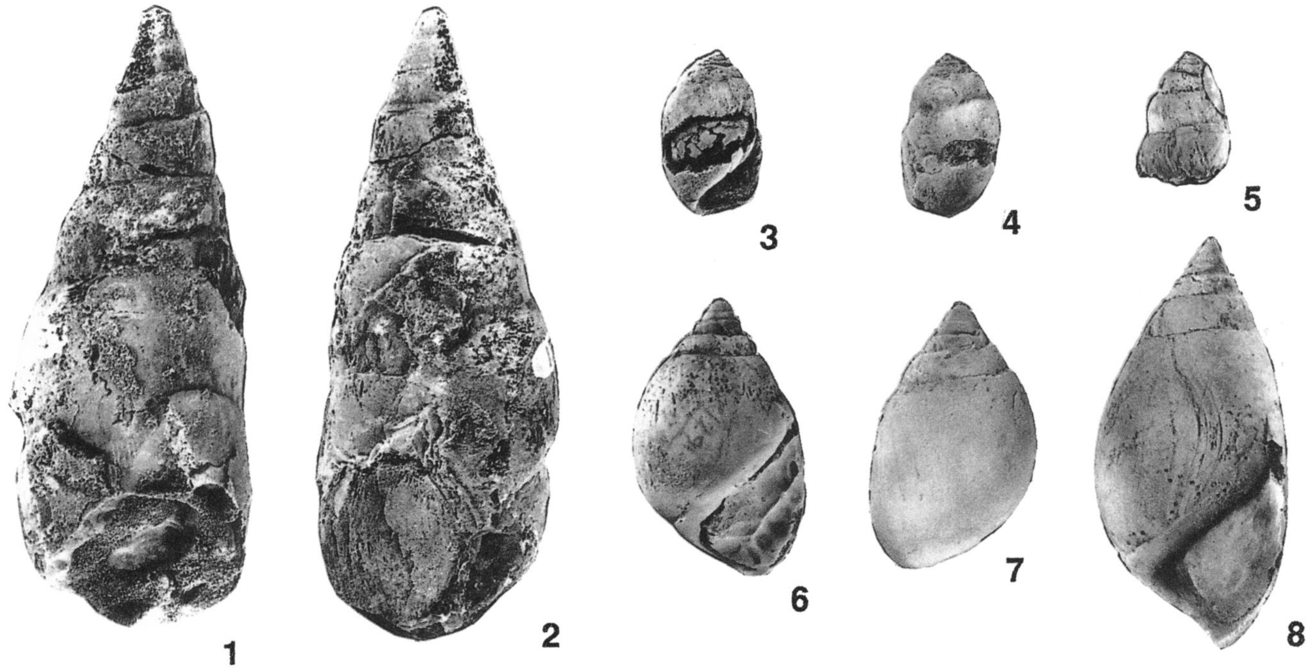


FIGURE 3—Albian and Cenomanian species of *Paosia* from the Pacific Slope of North American. All figures natural size and arranged in increasing specimen size for each species. *1, 2, Paosia acuminata* (Anderson, 1958), holotype, CAS 1345.03, CAS loc. 1345, apertural and abapertural views. *3–5, Paosia calafia* (Stewart, 1927), North Fork of Cottonwood Creek near Ono, northern California. *3, 4,* lectotype, ANSP 4287a, apertural and abapertural views. *5,* paralectotype, UCMP 11967 of ?*Acteonina pupoides* Gabb, 1864, abpertural view of spire. *6–8, Paosia colusaensis* (Anderson, 1958). *6, 7,* holotype, CAS 1291.05, CAS loc. 1291, apertural and abapertural views. *8,* hypotype, LACMIP 9823, LACMIP loc. 23474, apertural view.

having a projected and curved anterior end of the outer lip. Additional differences are listed below. *Paosia* differs from *Acteonina* by having much larger size, generally more inflated shape, rounded rather than tabulate whorls, much more sinuous growth lines, and no columellar fold(s). *Paosia* differs from *Euchrysalis* by having a much larger size and an overall elongate-conical shape rather than a spindle shape. *Paosia* differs from *Pseudomelania* by having much fewer and less convex spire whorls. *Paosia* differs from *Chemnitzia* by having a much larger size, a much less acuminate shell, a proportionally larger aperture, and absence of collabral ribs. *Paosia* differs from *Phasianella* by having sinuous growth lines, much less convex whorls, and an absence of spiral sculpture.

Paosia can resemble high-spired forms of *Tylostoma* Sharpe, 1849, whose geologic range is Late Jurassic (Kimmeridgian) (Cossmann, 1925) to early Paleocene (Danian) (Kollmann and Peel, 1983) and whose distribution is Tethyan and marginally Tethyan (Cossmann, 1925). *Paosia* differs from *Tylostoma* by having a less plump last whorl, no varices on the last whorl, a projected and incurved outer lip, usually more sinuous growth line, spire whorls that slightly overlap, less impressed sutures, and more common presence of a callus band. *Tylostoma* is an enigmatic naticiform genus that most workers, until recently, believed to be a naticid. Kase and Ishikawa (2003) reported *Tylostoma* to be an ampullospirid, but Squires and Saul (2004) reported it to be a tylostomatid.

Paosia is similar to the Late Cretaceous (Cenomanian to Late Cretaceous) (Cossmann, 1904) *Pterodonta* d'Orbigny, 1842. *Paosia* differs from the enigmatic and poorly defined *Pterodonta* by having a much less globose adult last whorl, lower spire, anterior end of outer lip projected and incurved, a more sinuous growth line, and in lacking an umbilicus. Kollmann (1985) placed *Pterodonta* in the stromboidean family Columbellinidae Fischer, 1884.

Paosia resembles the Jurassic to Miocene (Wenz, 1943) naticiform pseudamurid (see Bandel, 1999) *Ampullina* Bowdich, 1822, but differs by having a parasigmoidal growth line (rather than a prosocline one), a callus band, and a projected and curved anterior end of the outer lip. *Paosia* is somewhat similar to the smooth-shouldered species of the Cenomanian to Maastrichtian (Sohl and Kollmann, 1985) actaeonellid *Trochactaeon* (*Trochactaeon*) Meek, 1863, but differs by having a callus band, a projected and curved anterior end of the outer lip, and no columellar folds.

PAOSIA ACUMINATA (Anderson, 1958)
Figure 3.1, 3.2

Trajanella acuminata ANDERSON, 1958, p. 161–162, pl. 21, fig. 5.
non *Trajanella acuminata* KOLLMANN, 1979, p. 44, pl. 6, figs. 72, 73 = *Paosia kollmanni* new name.

Diagnosis.—Large *Paosia* with subturreted and acuminate spire.

Description.—Shell large (estimated 100 mm in height), elongate conical. Protoconch unknown. Pleural angle approximately 29 degrees. Teleoconch whorls approximately eight, sides flattish to lowly convex. Suture weakly? impressed. Spire acuminate and subturreted. Last whorl cylindrical. Whorls smooth. Aperture and growth line unknown.

Type locality.—CAS loc. 1345 (exact location unknown).

Material examined.—Holotype, CAS 1345.03, only known specimen.

Occurrence.—Upper lower Albian (*Brewericeras hulenense* zone). Budden Canyon Formation, Chickabally Mudstone Member, Texas Springs, southwest of Redding, Shasta County, northern California.

Discussion.—The holotype is a weathered, incomplete adult specimen 82 mm in height, 30 mm in diameter, and consisting of approximately seven whorls. Even though it is missing its aperture, Anderson described it as being elongate-ovate. The figure that accompanies his description also shows that the aperture is missing. Anderson (1958) described the growth lines as vertical, but what he observed are actually vertical lineations imparted by weathering on a patch of shell on the last whorl. The anterior parts of some of the upper spire whorls appear slightly concave, but this is likely due to weathering.

Kollmann (1979) named a *Trajanella acuminata* Kollmann (1979, p. 44–45, pl. 6, figs. 72, 73) from middle Albian to lower Cenomanian strata of northern Austria, but Kollmann's name is a junior homonym of Anderson's (1958) name. We change, therefore, the name *T. acuminata* Kollmann to *Paosia kollmanni* new name. *Paosia acuminata* differs from *P. kollmanni* n. name by having subturreted spire whorls and more distinct sutures.

PAOSIA CALAFIA (Stewart, 1927)
Figure 3.3–3.5

?*Acteonina pupoides* GABB, 1864, p. 113, pl. 19, fig. 67.
Acteonina pupoides GABB, 1869, p. 173, pl. 28, fig. 57.
non *Acteonina pupoides* D'ORBIGNY, 1850, p. 176, pl. 288, figs. 1, 2.
"*Acteonina*" *calafia* STEWART, 1927, p. 432, pl. 21, fig. 12.
Acteonina calafia STEWART. ANDERSON, 1938, p. 136.
Acteonina califia STEWART. ANDERSON, 1958, p. 158.

Diagnosis.—Very small *Paosia* with an overall pupoid shape.

Description.—Shell small (up to 21 mm in height), pupoid-shaped. Protoconch unknown. Pleural angle 65 degrees. Teleoconch whorls approximately five. Suture slightly to moderately impressed; suture descends more rapidly on last whorl than elsewhere. Whorls smooth, overlapping slightly. Shell height/shell diameter ratio approximately 1.6. Spire low to moderately low, approximately 17 percent of shell height. Penultimate whorl swollen; last whorl flat-sided and cylindrical. Aperture crudely comma-shaped. Outer lip thin? Columella smooth with thin callus. Callus band weakly developed, abaxial margin well delineated. Growth line incompletely known, prosocline near suture with small abapertural bend immediately next to suture.

Type locality.—"North Fork of Cottonwood Creek, Shasta County," northern California (Gabb, 1864, p. 114) (location very poorly known, see "Stratigraphy").

Material examined.—Lectotype ANSP 4287a, designated here; paralectotype ANSP 4287b, designated here; and paralectotype UCMP 11967; all from the type locality.

Occurrence.—Possibly Aptian or Albian. North Fork of Cottonwood Creek, Bald Hills near Ono, Shasta County, northern California.

Discussion.—Even though Stewart (1927) did not state that *calafia* is a replacement name for the preoccupied name *Acteonina pupoides* d'Orbigny, 1850, he mentioned that Gabb's name was a homonym, chose a holotype from among Gabb's specimens, and put Gabb's name in synonymy without question. According to ICZN Article 72e (Ride et al., 1985), a replacement name must have the same type specimen as the name that is being replaced. Gabb, however, did not select a holotype for *pupoides*. We, therefore, select ANSP 4287a as the lectotype of *pupoides*, and this specimen is the same one that was picked by Stewart as the holotype of his *calafia*. Thus, the ICZN rule is followed.

Only three specimens of *P. calafia* are known. They are small in size and are probably juveniles. All were collected by Gabb and indicated to be from the North Fork of Cottonwood Creek, but the exact location of the type locality is not defined (see "Stratigraphy"). No additional specimens of this species have been collected since Gabb's original work in 1864.

One of Gabb's (1864) specimens (ANSP 4287a = lectotype of *Acteonina calafia*) (Fig. 3.3, 3.4) served as the basis for a line drawing (Gabb, 1869, pl. 28, fig. 57) and this specimen is nearly complete. The curvature of its spire slightly to the right is probably the result of postburial compaction because the other specimens of this species have normal spires. Why Gabb did not initially include this particular specimen is unknown, but perhaps it was not cleaned of matrix until later. The second of Gabb's specimens (UCMP 11967) (Fig. 3.5) served as the basis for a line drawing (Gabb, 1864, pl. 19, fig. 67), but this specimen lacks most of the last whorl. The third specimen (ANSP 4287b) of Gabb's (1864) original material is missing the last whorl.

We considered the possibility that the specimens of *P. calafia* might be the tips of *P. acuminata* and *P. calafia*. However, the upper spire whorls of *P. calafia* are shorter than the corresponding ones on *P. acuminata*.

As mentioned under "Stratigraphy," the exact geologic age of *P. calafia* is unknown. In addition to the North Fork of Cottonwood Creek locale, Anderson (1958) reported this species from the Peterson Ranch area north of Sites, Colusa County, northern California, and from an area west of Phoenix, Jackson Creek, southwestern Oregon. No available material supports the occurrences of *P. calafia* at either of these localities. In the absence of such specimens, we consider that Anderson might have mistaken poorly preserved specimens of *P. californica* for *P. calafia*.

PAOSIA COLUSAENSIS (Anderson, 1958)
Figure 3.6–3.8

Acteonina colusaensis ANDERSON, 1958, p. 158, pl. 21, fig. 14.
Trajanella californica (GABB). MURPHY AND RODDA, 1960, p. 839–841, pl. 101, fig. 30.

Diagnosis.—Small *Paosia*, both juveniles and adults tear-shaped with relatively high spire.

Description.—Shell small (up to 51.5 mm in height), tear-shaped. Protoconch unknown. Pleural angle 68 degrees on juveniles (less than 40 mm in height), approximately 53 degrees on late juvenile or early adult. Teleoconch whorls approximately six. Suture impressed, descending more rapidly on last whorl than elsewhere. Whorls overlap slightly. Whorls smooth, except for occasional incised growth line. Shell height/shell diameter ratio approximately 1.6 on juveniles, approximately 2.1 on adults. Spire moderately low, approximately 22 to 25 percent of shell height; spire profile overall concave on juveniles, much less so on adults. Last whorl swollen in juveniles, becoming narrower and more elongate in adults. Aperture crudely comma-shaped, posteriorly constricted. Outer lip thin, long, with anterior end projected and incurved. Columella smooth with callus. Callus band well developed, abaxial margin well delineated. Growth lines parasigmoidal, with strongest deflections at medial part of last whorl and adjacent to callus-band margin.

Type locality.—CAS loc. 1291 (exact location unknown, see "Stratigraphy").

Material examined.—Holotype, CAS 1291.05; hypotype, LACMIP 9823, LACMIP loc. 23474; and two CAS specimens: 1291.07 (CAS loc. 1291) and 69111.03 (CAS loc. 69111).

Occurrence.—Upper Albian to Cenomanian. UPPER ALBIAN TO CENOMANIAN: Budden Canyon Formation, Bald Hills Member, North Fork of Cottonwood Creek, Bald Hills near Ono, Shasta County, northern California. PROBABLY UPPER ALBIAN TO LOWER CENOMANIAN (UNDIFFERENTIATED): Great Valley Group, either in lower part of informal Antelope Shale, "Peterson Ranch," or in submarine-slump deposits containing reworked late Albian fossils in basal part of Venado Sandstone Member of informal Cortina Formation, north of Sites, Colusa County, northern California (type locality area).

Discussion.—The holotype is a nearly complete juvenile specimen 36 mm in height, 12.5 mm in diameter, and consisting of six whorls. Specimen CAS 1291.07 is also a juvenile and from the same locality. The other two studied specimens are early adults and both are from North Fork of Cottonwood Creek.

Compared to our description of *P. colusaensis*, Murphy and Rodda (1960, p. 841) likewise noted "a great deal of variation in the inflation of the spire height even in specimens from a single locality," and, furthermore, they commented that "the amount of variation between specimens from a single locality is as much as the variation among specimens of all localities."

Paosia colusaensis is similar to *Paosia californica* but differs by being smaller, having a more inflated last whorl, and having no spiral grooves on the last whorl.

PAOSIA CALIFORNICA (Gabb, 1864)
Figure 4.1–4.16

Acteonina californica GABB, 1864, p. 114, pl. 19, fig. 68; ANDERSON, 1958, p. 156–157, pl. 29, fig. 1.
"*Acteonina*" *californica* GABB. STEWART, 1927, p. 433, pl. 24, fig. 21.
Acteonina bellavistana ANDERSON, 1958, p. 157, pl. 29, fig. 2.
Acteonina berryessensis ANDERSON, 1958, p. 157, pl. 29, fig. 3.
Acteonina yrekensis ANDERSON, 1958, p. 157–158, pl. 75, fig. 2.
Acteonina roguensis ANDERSON, 1958, p. 158, pl. 30, figs. 5, 5a.
Oonia? *californica* (GABB). JONES, SLITER, and POPENOE, 1978, pl. 1, fig. 12.
non "*Trajanella*" *californica* (GABB). MURPHY AND RODDA, 1960, p. 839–841, pl. 101, fig. 30 = *P. colusaensis* (ANDERSON, 1958).

Diagnosis.—Medium *Paosia*, both juveniles and adult relatively elongate with high spire and moderately convex cylindrical last whorl; some specimens with portions of shell covered by very fine spiral grooves and some adults with last whorl nearly parallel sided.

Description.—Shell medium, commonly no larger than 65 mm in height (rarely up to 85 mm in height, estimated), elongate-conical to subcylindrical. Protoconch unknown. Pleural angle approximately 51 degrees on early juveniles (less than 50 mm height), 22 to 46 degrees on adults (rarely less than 35 degrees). Teleoconch whorls approximately seven. Suture moderately impressed to somewhat adpressed, descending more rapidly on last whorl than elsewhere. Whorls overlap slightly. Whorls commonly smooth, except for occasional growth rugae and incised growth lines. Whorls of late juvenile and early adult specimens occasionally with numerous, very fine, and closely spaced spiral grooves on spire whorls and posterior part of last whorl near aperture of specimens and on anterior part of last whorl adjacent to callus band. Shell height/shell diameter ratio approximately 2.0. Spire moderately high, approximately 27 to 32 percent of shell height. Spire whorls flattish to moderately convex, becoming more convex on more mature whorls. Last whorl slightly swollen to nearly parallel sided. Aperture crudely comma-shaped. Outer lip thin, interior smooth, anterior end projecting and curved. Columella smooth with moderately thin but distinct callus. Callus band weakly to moderately well developed, abaxial margin weakly to well delineated. Growth lines parasigmoidal, with strongest deflections at medial part of last whorl and adjacent to callus-band margin.

Type locality.—Of *californica*, CAS loc. 31918; of *roguensis*, CAS loc. 61906; of *bellavistana*, CAS loc. 1293; of *berryessensis*, CAS loc. 31920; of *yrekensis*, CAS loc. 61847.

Material examined.—Lectotype, UCMP 11968, designated here; "neotype," CAS 31918.01 of *californica*; holotype, CAS 61906.01 of *roguensis*; holotype, CAS 1293.01 of *bellavistana*; holotype, CAS 31920.01 of *berryessensis*; holotype, CAS 61847.01 of *yrekensis*; hypotypes, LACMIP 8071–8075 (see caption of Fig. 4 for localities); and 124 uncatalogued specimens (most from LACMIP collection).

Occurrence.—Upper Cenomanian to Turonian. UPPER CENOMANIAN: Hornbrook Formation, Osburger Gulch Sandstone Member, Jackson County, southwestern Oregon; Great Valley Group, upper part of informal Antelope Shale, near Sites, Colusa County, northern California (new information). TURONIAN: Unnamed formation of Nanamio Group at Hamley Point, Sidney Island, one of the southernmost Gulf Islands, south of Nanaimo and north of Victoria, east coast of Vancouver Island, British Columbia (new information); possibly the Hornbrook Formation, Osburger Gulch Sandstone Member, "Forty-nine mine" near Phoenix, Jackson County, southwestern Oregon; Hornbrook Formation, Osburger Gulch Member, near Yreka, Siskiyou County, northern California; Redding Formation, Frazier Siltstone Member, east of Redding, Shasta County, northern California; Great Valley Group, reworked specimens in Rumsey Formation (informal), Guinda Sandstone Member near Fruto, Glenn County, northern California (new information); Cortina Formation (informal), Venado Sandstone Member, near Sites, Colusa County, and near Fruto, Glenn County, northern California; Yolo Formation, Thompson Canyon, Yolo County, northern California; Great Valley Group, near Martinez, Contra Costa County (lectotype locality area) and Benicia, Solano County, northern California; Ladd Formation, lower Holz Shale, Santa Ana Mountains, Orange County, southern California (new information); and possibly Morro Redondo Formation, Cedros Island, Baja California, Mexico.

Discussion.—Many of the studied specimens are incomplete and weathered. Those from British Columbia have been somewhat crushed. The most numerous ones are from east of Redding in northern California. Growth series of specimens occur in the Little Cow Creek area, east of Redding, at LACMIP localities 10735, 10738, and 15736.

As described above, there is considerable variation in shape between juvenile and adult specimens and there is variation in shape among adult specimens. Stewart (1927, p. 433) noticed a "considerable variation in the height of the spire" of the specimens comprising just the primary type material of *P. californica.*

Having ample specimens and growth series available for study enabled us to put the holotypes of *Acteonina roguensis* (Fig. 4.1, 4.2), *Acteonina bellavistana* (Fig. 4.7, 4.8), *A. berryessensis* (Fig. 4.9, 4.10), and *A. yrekensis* (Fig. 4.13, 4.14) into synonymy with *P. californica*. The holotype of *A. berryessensis* is an example of one of the more subcylindrical adult forms of *P. californica*.

There has been confusion regarding the primary type material of this species. Gabb (1864) reported that a total of six specimens were found by him at various localities in northern California: near Martinez in Contra Costa County, 3.2 km north of Benicia in Solano County, and a single specimen 12.8 km north of Yreka, Siskiyou County. He did not designate a holotype. Gabb's (1864, pl. 19, fig. 68) outline drawing was made from several fragmentary specimens and, according to Anderson (1958), from two or more localities. Stewart (1927) reported that two [actually there are three] of the six specimens are in the ANSP collection and contained in a box labelled "Benicia," and that five fragmentary specimens are at UCMP and are labeled in Gabb's handwriting, "eight miles north of Yreka and Martinez." Anderson (1958) surmised that "eight miles north of Yreka" evidently referred to the Hagerdorn Ranch, 6.4 km north of Montagu, Siskiyou County, where Late Cretaceous mollusks are plentiful. The holotype of *Acteonina yrekensis* is from the Hagerdorn Ranch.

Anderson (1958, p. 156, pl. 29, fig. 1) choose a specimen from the Yolo Formation at Thompson Canyon, Yolo County (CAS 31918) as the "neotype" of *A. californica* (Fig. 4.16). Anderson's designation, however, is invalid because Gabb's original material

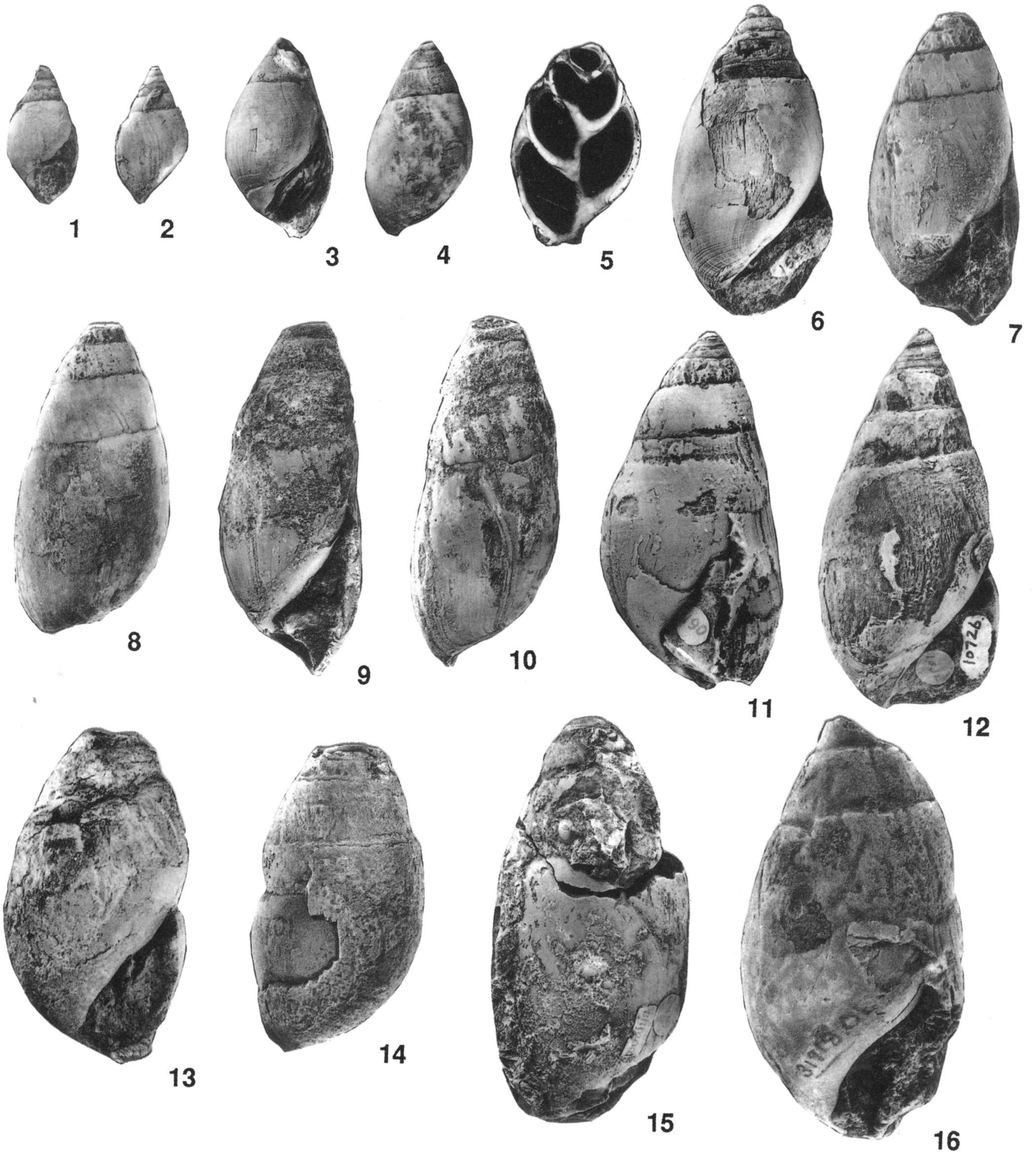


FIGURE 4—Turonian *Paosia californica* (Gabb, 1864) from the Pacific Slope of North America. All figures natural size and arranged in increasing specimen size for each species. *1, 2,* holotype, CAS 61906.01 of *Acteonina roguensis* Anderson, 1958, CAS loc. 445, apertural and abapertural views. *3, 4,* hypotype, LACMIP 8071, LACMIP loc. 17741, apertural and abapertural views. *5,* hypotype, LACMIP 8072, LACMIP loc. 10735, longitudinal section showing columella. *6,* hypotype, LACMIP 8073, LACMIP loc. 15839, apertural view. *7, 8,* holotype, CAS 1293.01 of *Acteonina bellavistana* Anderson, 1958, CAS loc. 1293, apertural and abapertural views. *9, 10,* holotype, CAS 31920.01 of *Acteonina berryessensis* Anderson, 1958, CAS loc. 31920, apertural and abapertural views. *11,* hypotype, LACMIP 8074, LACMIP loc. 10728, apertural view. *12,* hypotype, LACMIP 8075, LACMIP loc. 10726, apertural view. *13, 14,* holotype, CAS 61847.01 of *Acteonina yrekensis* Anderson, 1958, Hagerdorn Ranch near Yreka, northern California, apertural and abapertural views. *15,* lectotype, UCMP 11968, northeast of Martinez, northern California, left-lateral view. *16,* "neotype," CAS 31918.01 of *Acteonina californica* Gabb, 1864, CAS loc. 31918, apertural view.

had not been lost. In addition, Anderson's proposed "neotype" is not from any of the localities listed by Gabb. Stewart did not select a lectotype from Gabb's material. We have studied Gabb's Martinez and Benicia specimens, and all are very poorly preserved. The best preserved one is from the Martinez material and we designate it (UCMP 11968) as the lectotype (Fig. 4.15).

Acteonina roguensis was originally based on a single, early juvenile specimen from the "Forty-nine mine" near Phoenix, Jackson County, southwestern Oregon. During this present study, we came across two other specimens from this same locality (CAS 445). These additional specimens are both late juveniles.

A tip of a specimen of *Paosia* sp. from the Morro Redondo Formation at the southeast corner of Cedros Island, Baja California, Mexico, was referred to as *Oonia*(?) sp. by Kilmer (1984, p. 32). This specimen is possibly *P. californica*.

Paosia californica is similar to "*Trajanella*" *laubeana* (Geinitz, 1874, pl. 53, fig. 1a, 1b [as *Euchrysalis*]) from Cenomanian strata of Germany, western Austria, Czech Republic, and northern Italy. For synonyms of "*T.*" *laubeana* see Rahman (1967, p. 38–39) and Kollmann (1979, p. 45). *Paosia californica* differs from "*T.*" *laubeana* by having a wider pleural angle, anterior end of outer lip projecting and incurved, and rarely occurring, faint spiral lirae on the spire whorls.

Paosia californica is also very similar to "*Trajanella*" *dutoiti* Rennie (1930, p. 210–211, pl. 24, figs. 16–18) from strata in Pondoland, South Africa, that are correlative (Klinger and Kennedy, 1977) to the upper Santonian to lower Campanian. *Paosia californica* differs from "*T.*" *dutoiti* by having a less projecting anterior end of the outer lip, as well as having rarely occurring, faint spiral lirae on the spire whorls.

Paosia californica is similar to "*Trajanella*" (*Paosia*) sp. Sohl (1987, fig. 6, in part), from presumably the lower Campanian Lucea Inlier [formerly Hanover Inlier] of northwestern Jamaica. *Paosia californica* differs from the Jamaican species, whose upper spire is missing, by having a more distinct suture.

Paosia californica is the most widespread and abundant species of *Paosia* from the Pacific Slope of North America.

Paosia ursula (Anderson, 1958)
Figure 5.1–5.11

Acteonina ursula Anderson, 1958, p. 158, pl. 63, fig. 4.
Acteonina ursulagorda Anderson, 1958, p. 159, pl. 63, fig. 5.

Diagnosis.—Medium *Paosia*, low spired; juveniles tear-shaped, adults moderately swollen cylindrical shape.

Description.—Shell medium (up to 64.7 mm in height), overall shape changing with growth stage, juveniles (less than 50 mm in height) moderately tear-shaped to broadly tear-shaped, adults moderately swollen cylindrical. Protoconch unknown. Pleural angle approximately 60 degrees on juveniles, approximately 70 degrees on adults. Teleoconch approximately seven whorls. Suture moderately impressed to somewhat adpressed; on some larger specimens suture descends more rapidly on last whorl than elsewhere. Whorls smooth, except for occasional incised growth line. Shell height/shell diameter approximately 1.7 on juveniles, approximately 1.8 on adults. Spire whorls slightly concave to flattish, becoming slightly convex with growth. Spire moderately low, approximately 20 percent of shell height on juveniles, approximately 17 percent on adults. Last whorl rather swollen on juveniles, becoming less so but more elongate on adults. Aperture crudely comma-shaped. Outer lip thin, interior smooth, anterior end projecting and incurved. Columella smooth with moderately thin but distinct callus. Callus band moderately to well developed, abaxial margin well delineated. Growth lines parasigmoidal, with strongest deflections at medial part of last whorl and adjacent to callus-band margin.

Type locality.—Of *ursula* and *ursulagorda*, both from CAS loc. 31210.

Material examined.—Of *ursula*, holotype, CAS 31210.01; of *ursulagorda*, holotype, CAS 31210.02; hypotypes, LACMIP 8076–8078 (see caption of Fig. 5 for localities); and 67 uncatalogued LACMIP specimens.

Occurrence.—Coniacian. Redding Formation, Bear Creek Sandstone Member of Haggart (1986) (=type locality area) and Member IV of Matsumoto and Popenoe *in* Matsumoto (1960), both east of Redding, Shasta County, northern California.

Discussion.—This species is most abundant at LACMIP locality 10816 in Member IV, where 30 specimens, which form a growth series, were collected. Seventeen specimens were collected from LACMIP locality 10758 in the Bear Creek Sandstone Member. Additional Bear Creek Sandstone Member specimens were collected from LACMIP localities 10821 and 15795.

The more globose specimens (e.g., holotype of *P. ursulagorda*) of *Paosia ursula* are similar to *Paosia fadaltensis* (Böhm, 1895, p. 146, pl. 15, figs. 1–4; Wenz, 1943, fig. 4199), the type species of *Paosia*, from Turonian strata of the southern Alps. These globose specimens of *P. ursula* differ from *P. fadaltensis* by having a much smaller size and a more distinct suture.

Paosia pentzensis new species
Figure 5.12–5.17

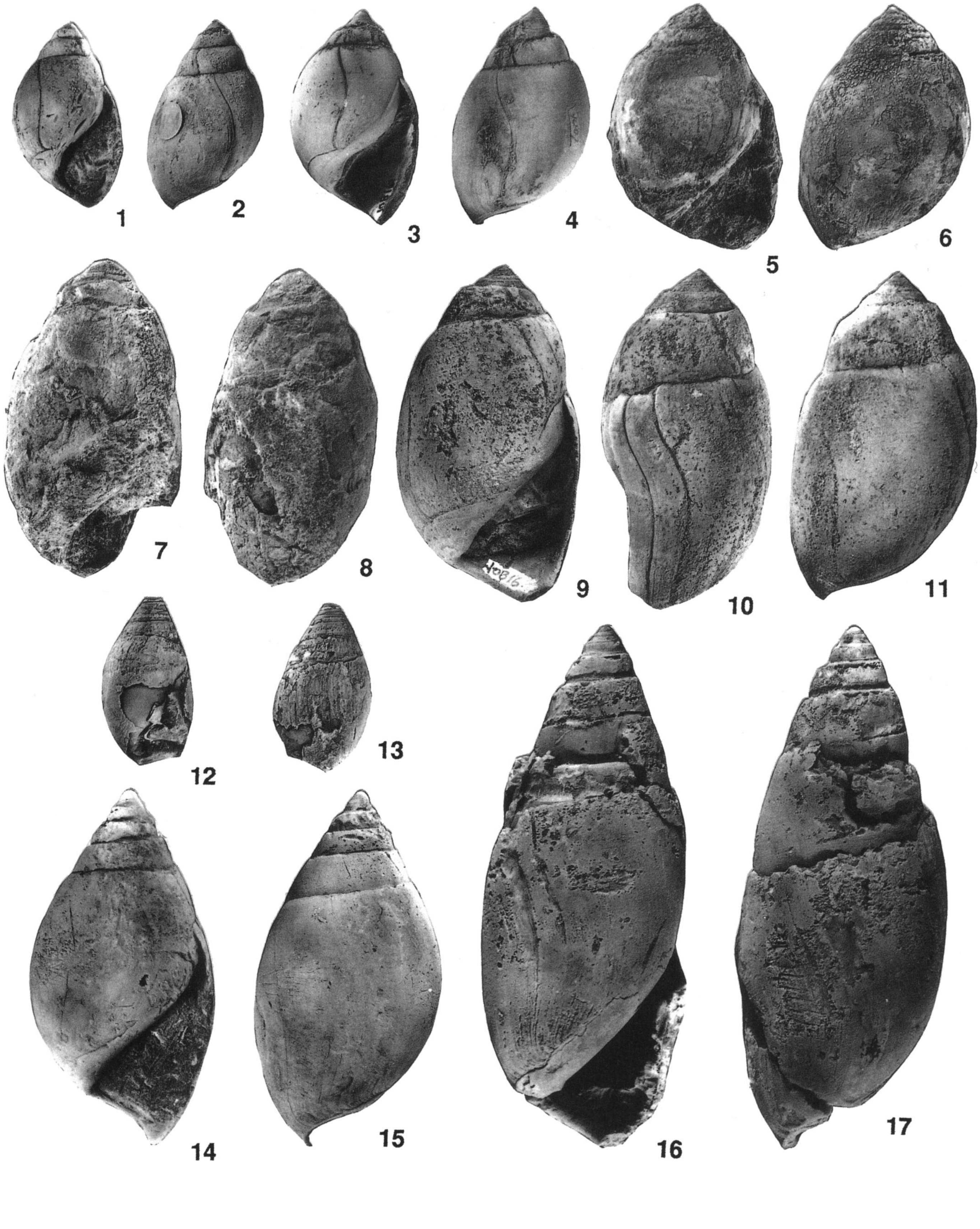
Eoacteon cf. *linteus* Conrad. Ludvigsen and Beard, 1994, p. 93–94, fig. 58, two views; 1997, p. 112–113, fig. 69, two views.

Diagnosis.—Large *Paosia*, high-spired; juveniles tear-shaped, adults very elongate-cylindrical shape.

Description.—Large (up to 97 mm in height). Protoconch apparently domal and smooth. Pleural angle approximately 63 degrees on juveniles (less than 65 mm in height), approximately 37 degrees on adults. Teleoconch whorls approximately seven. Suture moderately impressed; whorls slightly overlapping. Whorls smooth. Shell height/shell diameter approximately 1.9 in juveniles, approximately 2.5 in adults. Spire moderately high, approximately 24 percent of shell height on juveniles, approximately 27 percent on adults. Last whorl swollen-ovate in juveniles and early adults, elongate-cylindrical in adults with nearly parallel sides. Aperture crudely comma-shaped, posteriorly constricted. Outer lip thin, interior smooth; anterior end projecting and incurved.

→

Figure 5—Coniacian, Santonian, and Campanian species of *Paosia* from the Pacific Slope of North America. All figures natural size and arranged in increasing specimen size for each species. *1–11*, *Paosia ursula* (Anderson, 1958). *1, 2*, hypotype, LACMIP 8076, LACMIP loc. 24104, apertural and abapertural views. *3, 4*, hypotype, LACMIP 8077, LACMIP loc. 10816, apertural and abapertural views. *5, 6*, holotype, CAS 31210.02 of *Acteonina ursulagorda* Anderson, 1958, CAS loc. 31210, apertural and abapertural views. *7, 8*, holotype, CAS 31210.01 of *Acteonina ursula* Anderson, 1958, CAS loc. 31210, apertural and abapertural views. *9–11*, *Paosia ursula*, hypotype LACMIP 8078, LACMIP loc. 10816, apertural, right-lateral, and abapertural views. *12–17*, *Paosia pentzensis* n. sp. *12, 13*, paratype, RBCM.EH2003.005.0001, GSC loc. 103851, apertural and abapertural views. *14, 15*, paratype, LACMIP 7316, LACMIP loc. 17611, apertural and abapertural views. *16, 17*, holotype, LACMIP 7315, LACMIP loc. 17611, apertural and abapertural views.



Columella smooth with small, distinct protuberance near anterior end on late-stage adults. Anterior of last whorl with callus band, abaxial margin well delineated. Growth lines parasigmoidal, with strongest deflection coincident with medial part of last whorl; adaxially bent adjacent to callus band.

Etymology.—The species is named for the Pentz area, Butte County, northern California.

Types.—Holotype, LACMIP 7315 (nearly complete adult of seven whorls, 94.6 mm in height, 37 mm in diameter); paratype, LACMIP 7316, LACMIP loc. 17611; paratype, RBCM.EH2003.005.0001 [=VIPM 045], GSC loc. 103851.

Other material examined.—Two uncatalogued LACMIP specimens (discussed below).

Occurrence.—Upper Santonian to lower Campanian, and possibly middle Campanian. UPPER SANTONIAN TO LOWERMOST CAMPANIAN: Haslam Formation of Nanamio Group at Brannan Lake, west of Nanaimo, along east side of Vancouver Island, British Columbia. LOWER CAMPANIAN: Chico Formation, Pentz Road member (informal), at Pentz, Butte County, northern California (type locality area); Ladd Formation, upper Holz Shale Member, including fossils derived from this member and redeposited in upper lower Campanian basal conglomerate of Williams Formation, Schulz Member, Santa Ana Mountains, Orange County, southern California. POSSIBLY UPPER MIDDLE CAMPANIAN: Williams Formation, lower part of Pleasants Sandstone Member, Santa Ana Mountains, Orange County, southern California.

Discussion.—Paratype, RBCM.EH2003.005.0001 (Fig. 5.12, 5.13) is a juvenile from the Haslam Formation. It is the same specimen figured by Ludvigsen and Beard (1994, 1997) and identified by them as "*Eoacteon* cf. *linteus*." *Eoacteon linteus* (Conrad, 1858, p. 334, pl. 35, fig. 10; Sohl, 1964, p. 289, pl. 47, figs. 5, 10–12) from upper Maastrichtian strata in Mississippi, however, is characterized by incised punctate spiral grooves, as well as a columella with one fold not visible at the aperture.

One of the uncatalogued specimens of *P. pentzensis* n. sp. is from the middle Holz Shale Member at LACMIP locality 10093 and is of early Campanian age. The other uncatalogued specimen is from LACMIP locality 27199 in the Schluz Member of the Williams Formation and probably represents material reworked from the underlying upper lower Campanian, upper Holz Shale Member. This latter specimen is the only confirmed specimen of the new species from southern California.

Two additional specimens might be the new species. Both are internal molds. One is from the upper Holz Shale Member at LACMIP locality 22949 and is of early Campanian age. This specimen is missing its spire, but its 45-mm-wide last whorl is the largest known for this species. The other internal mold is from LACMIP locality 10119 in the lower part of the Pleasants Sandstone Member, and this part of the formation is upper middle Campanian.

On the basis of the adult size, *P. pentzensis* n. sp. is most similar to *P. acuminata*, but the former commonly has a wider pleural angle, and the uppermost spire is not as acuminate nor subturreted. On the basis of overall shape, *P. pentzensis* n. sp. is most similar to *P. californica*, but the former differs by having a much larger size, wider pleural angle on juvenile specimens, and better-developed callus. In addition, on same-sized individuals about 60 to 70 mm in shell height (i.e., juveniles of *P. pentzensis* n. sp. and adults of *P. californica*), *P. pentzensis* n. sp. has a more convex last whorl. Early adult specimens (approximately 65 mm in height) of the new species are very similar to adult specimens (approximately 50 mm in height) of *Paosia colusaensis*, but older adults of the new species are much larger and have a very elongate and cylindrical last whorl, rather than a moderately swollen one.

The new species is very similar to "*Trajanella*" *dutoiti* Rennie (1930, p. 210–211, pl. 14, figs. 16–18) from middle or upper Santonian to lower Campanian strata in Pondoland, South Africa. The new species differs from "*T.*" *dutoiti* by having a narrower last whorl on adult specimens. Both species reach approximately the same large size, with the new species being slightly larger. In addition, the new species has a wider and more distinct callus and the anterior end of the outer lip is projected. On "*T.*" *dutoiti*, the medial part of the extreme anterior part of the aperture is projected.

The new species is similar to "*Trajanella*" (*Paosia*) sp. Sohl (1987, fig. 6, in part; = "*Trajanella*" (*Paosia*) sp. Sohl, 1967, p. 5, pl. 1, fig. 8) from Campanian strata in the Lucea Inlier [=Hanover Inlier], east of Lucea, northwestern Jamaica. Sohl's (1967, 1987) referral of "*Trajanella*" (*Paosia*) sp. to the Campanian was based on the co-occurrence of the "*Trajanella*" with a species of *Turritella*, but more biostratigraphic details are needed to confirm the geologic age. *Paosia pentzensis* n. sp. has a narrower last whorl on adult specimens than does the Jamaican material. Both species reach approximately the same large size (i.e., 90 to 95 mm in height). The morphology of the upper spire of the Jamaican species is not known.

PAOSIA species indeterminate

Discussion.—Early spire whorls of two *Paosia* specimens from LACMIP locs. 23623 and 23625 in the middle Santonian part of the Musty Buck Member of the Chico Formation do not have enough of the shell present to be assigned to species.

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APPENDIX

Localities Cited.

Localities are LACMIP, unless otherwise stated. All the quadrangle maps listed below are U.S. Geological Survey maps.

CAS 445. [=CAS 61906].—At the old "Forty-nine mine" 3.2 km south of Phoenix, Jackson County, southwest Oregon. Turonian. Collectors: Unknown.

CAS 1291.—Peterson ranch, 6.4 km north of Sites, west side of Sacramento Valley, Colusa County, northern California. "Locality" probably along west section line of sec. 33, T18N, R4W, Lodoga Quadrangle (15 minute, 1943). Great Valley Group, Cenomanian fossiliferous strata with lenses containing reworked late Albian fossils. Collectors: Unknown.

CAS 1293.—1.6 km north of Fraziers Corners (Bella Vista), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Turonian. Collector: B. L. Cunningham.

CAS 1345.—In sandstone on southwest side of road leading to Centerville, SE1/4 of SW1/4 of sec. 30, T31N, R5W, Redding Quadrangle (7.5 minute, 1969), at Texas Springs, 3.2 km southeast of Centerville, southeast of Ono, Shasta County, northern California. Budden Canyon Formation, Chickabally Mudstone Member. Age: Late early Albian. Collector: F. M. Anderson.

CAS 31210.—Bear Creek, a little below mouth of Snow Creek, above Inwood, Whitmore Quadrangle (15 minute, 1956), Tehama County, northern California. Redding Formation, Bear Creek Sandstone Member. Coniacian. Collectors: W. B. Aldrich and S. McKoy.

CAS 31918. [=CAS 31920].—Nodular body of fossiliferous sandstone in Thompson Canyon, a small tributary of Putah Creek, 0.8 km west of the Napa-Yolo County line, and about same distance north of main stream, 183 m west and 366 m north from southeast corner of sec. 20, T8N, R2W, Monticello Dam Quadrangle (7.5 minute, 1959), Yolo County, northern California. Yolo Formation. Turonian. Collector: W. E. Kennett, July 1943.

CAS 31920.—See CAS 31918.

CAS 61847.—Hagerdorn Ranch, 6.4 km north of Montague, Siskiyou County, northern California. Hornbrook Formation, Osburger Gulch Member. Turonian. Collector: unknown.

CAS 61906.—See CAS 445.

CAS 69111.—North Fork of Cottonwood Creek, Shasta County, northern California.

GSC 103851.—Lower shale quarry, Dumont Road, southwest of Brannan Lake, just west of Nanaimo, British Columbia, Canada (approximate coordinates latitude 49°11′45″, longitude 124°06′00″W). Haslam Formation. Age: Late Santonian to earliest Campanian. Collector: G. Beard, 5 November 1982.

10019. [=CIT 89].—Sandstone above basal conglomerate, 259 m south and 472 m east of northwest corner of sec. 29, T5S, R7W, El Toro Quadrangle (7.5 minute, 1949), Orange County, Santa Ana Mountains, southern California. Williams Formation, lower part of Pleasants Sandstone Member. Age: Late middle Campanian. Collector: B. N. Moore, 1928.

10093. [=CIT 1035]. Pebbly lens near top of shale series below crest of ridge on first prominent NE-SW spur north of Santiago Creek near its junction with Harding Creek. Approximately 914 m straight west of the dam in Harding Canyon, El Toro Quadrangle (7.5 minute, 1968), Santa Ana Mountains, Orange County, southern California. Middle Holz Shale Member. Ladd Formation, middle Holz Shale Member. Age: Early Campanian. Collector: W. P. Popenoe, 9 April 1934.

10726. [=CIT 1032].—Shales exposed in left bank of Dry Creek, to the east of the road and 2.1 km north of Bellavista [=Fraziers Corners], NW1/4 of SW1/4 of sec. 5, T32N, R3W, Millville quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Turonian. Collectors: W. P. Popenoe and W. Findlay, 30 August 1933.

10728. [=CIT 1190].—553 m N16°20′ east of southeast corner of sec. 6, T32N, R3W, Millville quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Turonian. Collectors: W. P. Popenoe and C. Ahlroth, 19 June 1936.

10735. [=CIT 1212].—Hard sandy concretions in shale banks of gullies in pasture, about 1.2 km west of Alturas-Redding Highway bridge over Salt Creek, and 0.4 km south of highway, approximately 3.2 km northeast of Bellavista [=Frazier's Corners], SE1/4 of NE1/4 of sec. 4, T32N, R3W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Age: Turonian. Collectors: W. P. Popenoe and C. Ahlroth, 7 July 1936.

10738. [=CIT 1221].—About 0.4 km north of the Alturas-Redding Highway U.S. 299 and 2.6 km by road northeast of Bellavista [=Fraziers Corners], south-facing shale bank along small stream, NW1/4 of NW1/4 of sec. 9, or NE1/4 of NE1/4 of sec. 8, T32N, R3W, Millville quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Turonian. Collectors: W. P. Popenoe and C. Ahlroth, 29 June 1936.

10758. [=CIT 1596].—Float boulder in creek bed at forks of Snow and North Bear creeks, 381 m east and 838 m south of the northwest corner of sec. 7, T31N, R1E, Whitmore Quadrangle (15 minute, 1956), Shasta County, northern California. Redding Formation, Member V. Age: Late Coniacian. Collectors: W. P. Popenoe and W. M. Tovell, 10 September 1941.

10816. [=CIT 1007].—Hard limey sandstone outcropping on lower slope of hills north of Oak Run, approximately 0.4 km S26°E of northwest corner of sec. 16, T32N, R2W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member IV. Age: Coniacian. Collector: W. P. Popenoe and D. W. Scharf, 9 August 1931.

10821.—Float boulder in stream bed of Pine Timber Gulch at 341 m elevation, approximately in center of southeast quarter of sec. 8, T31N, R1W, Whitmore Quadrangle (15 minute, 1956), Shasta County, northern California. Redding Formation, Member V. Age: Probably late Coniacian. Collectors: W. P. Popenoe and V. Church, 11 August 1936.

15736.—Little Cow Creek, Millville Quadrangle (15 minute, 1958), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Age: Turonian. Collectors: Humble Oil Company employees, circa 1953–1954.

15795.—North Fork of Bear Creek, NW1/4 of SW1/4 of sec. 7, T31N, R1E, Whitmore Quadrangle (15 minute, 1956), Shasta County, northern California. Redding Formation, Member V. Age: Late Coniacian. Collector: Unknown.

15839.—Bed of Swede Creek, 549 m north and 137 m east of southwest corner of sec. 4, T32N, R2W, Millville quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Frazier Siltstone Member. Turonian. Collectors: W. P. Popenoe and M. A. Murphy, 1 June 1951.

17611.—Outcrop in streambed of Dry Creek, 472 m south and 152 m east of northwest corner of sec. 36, T21N, R3E, Cherokee Quadrangle (7.5 minute, 1970), Pentz area, Butte County, northern California. Chico Formation, Pentz Road member (informal). Age: Early Campanian. Collector: E. Göhre, 2000–2002.

17741. [=USGS M-174].—In contorted, deformed mudstone 640 m north, 137 m west of southeast corner of sec. 8, T18N, R4W, north side of Hunter Creek gorge through Logan Ridge, Lodoga quadrangle (15 minute, 1943), Glenn County, northern California. Cortina Formation (informal), Venado Sandstone Member (stratigraphic unit 8a and approximately 15 m above base). Turonian. Collectors: R. D. Brown and E. I. Rich, 1958.

22949.—Massive fossiliferous limey sandstones on left bank of Williams Canyon, approximately 30 m from stream bed, 122 m nearly due south of northwest corner of sec. 20, T5S, R7W, El Toro Quadrangle (7.5 minute, 1949), Santa Ana Mountains, Orange County, southern California. Ladd Formation, near top of upper Holz Shale Member, just below contact with Schulz Conglomerate Member. Age: Early Campanian. Collectors: W. P. Popenoe and students, January 1953.

23474.—Thick, massive graywacke bed on south side of Coyote Creek, 610 m south of northwest corner of sec. 30, T30N, R6W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member. Cenomanian. Collectors: P. U. Rodda and M. A. Murphy, August 1955.

23623.—Fossils in coarse, gray, well-cemented, poorly sorted sandstone with many stringers of sub- to well-rounded pebbles, on east bank of Big Chico Creek about 2 km south of Mickey's house, 747 m north and 366 m east of southwest corner of sec. 12, T23N, R2E. Paradise quadrangle (7.5 minute, 1953), Butte County, northern California. Chico Formation, Musty Buck Member. Age: Late early Santonian. Collectors: L. R. Saul and R. B. Saul, August 1952.

23625.—On E bank of Big Chico Creek, 610 m north and 290 m east of southwest corner of sec. 12, T23N, R2E, Paradise quadrangle (7.5 minute, 1953), Butte County, northern California. Chico Formation, Musty Buck Member. Age: Early Santonian. Collectors: L. R. Saul and R. B. Saul, August 1952.

24104. [=LACMIP 8133 = LACMIP 10869 = CIT 1034].—Hard-cemented sandstone slabs weathering out of siltstone about 183 m east and 457 m south of northwest corner of sec. 16, T32N, R2W, Millville quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member IV. Coniacian. Collector: W. P. Popenoe, 18 August 1959.

27199.—Between Fremont Canyon and Oak Flat along a south fork of Fremont Canyon at about 567 m elevation, 107 m north and 320 m east of southwest corner of sec. 7, T4S, R7W, Black Star Canyon Quadrangle (7.5 minute, 1949), northern Santa Ana Mountains, Orange County, southern California. Williams Formation, Schulz Member. Age: Late early Campanian. Collectors: W. P. Popenoe and J. E. Schoelhamer. 28 November 1951. [=loc. F38 in Schoellhamer et al., 1981].

UCMP A-4856.—Center of south line of northwest quarter of sec. 8, T19N, R4W, on south side of small hill approximately 0.4 km east of Bench Mark 289, Fruto Quadrangle (15 minute, 1958), Glenn County, northern California. Reworked Turonian-age material in Rumsey formation (informal), Guinda Sandstone Member. Collector: I. Valov, 1948.

USGS M-176.—In pebbly deformed mudstone, on Logan Ridge, 640 m north of northwest corner of sec. 33, T18N, R4W, on west line of sec. 33, 1,341 m southeast of point "1,009 ft" on Logan Ridge, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, stratigraphic unit 7c of Brown and Rich (1961) and approximately 12 m below base of Venado Sandstone Member of Cortina Formation (informal). Cenomanian. Collectors: R. D. Brown, Jr. and E. I. Rich, 1958.

USGS M-177.—In concretionary silty sandstone bed (approximately 1 m thick), 366 m north, 61 m east of southwest corner of sec. 33, T18N, R4W, 1,920 m south-southeast of point "1,009 ft" on Logan Ridge, Lodoga Quadrangle (15 minute, 1943), Colusa County, northern California. Upper part of Antelope Shale, stratigraphic unit 7c of Brown and Rich (1961) and approximately 23 to 30 m below base of Venado Sandstone Member of Cortina Formation (informal). Cenomanian. Collectors: R. D. Brown, Jr. and E. I. Rich, 1958.