DEPARTMENT OF THE INTERIOR
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Paleocene(?) and Eocene Pollen Samples from the General Region of the San Jose 2° Sheet, California

By

Norman O. Frederiksen[1]

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[1]Reston, Virginia

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Abstract

This report concerns 24 Paleocene(?) to middle Eocene pollen samples from Franciscan rocks of northern California, and one upper Eocene pollen sample from central California. Many of the species in these samples are the same as in Paleocene and Eocene rocks of southern California that are biostratigraphically well known; thus, the samples from central and northern California can be dated on the basis of their pollen content. This study shows that there should be no particular difficulty dating well preserved Eocene pollen assemblages from the San Jose 2° Sheet, California.

Introduction

Early Tertiary pollen assemblages of central and northern California are, in general, poorly known, and, at least in published papers, they have been used only to a limited extent for correlation. The purpose of this report is to provide descriptions and interpretations of 24 Paleocene(?) to middle Eocene pollen samples from Franciscan rocks of northern California, and one upper Eocene pollen sample from central California. The intention of this report is to evaluate the possibility of using pollen data to correlate Eocene rocks in the San Jose 2° Sheet, California.

Previous Palynological Work

Drugg (1967) described early Paleocene pollen assemblages from central California (fig. 1, loc. 5); this is the only published detailed study of early Tertiary pollen assemblages from central or northern California. Photomicrographs but no descriptions of early Eocene or early middle Eocene pollen grains from the central Sierra Nevada (fig. 1, loc. 3) were published by E. B. Leopold and B. D. Tschudy (in Penny, 1969). Generalized occurrences of some pollen taxa in Paleocene(?) and Eocene rocks of the Franciscan Coastal belt in northern California (fig. 1, locs. 1, 2) were reported by Evitt and Pierce (1975), but palynomorph correlation of Franciscan rocks in northern California has been done mainly on the basis of dinoflagellates rather than pollen (for example, by Evitt and Pierce, 1975; Damassa, 1979a, b; Sliter and others, 1986) in part because stratigraphic ranges of dinoflagellate taxa in California were better known than ranges of pollen taxa. Some localities studied by Evitt and Pierce (1975) and Sliter and others (1986) are in the vicinity of localities studied for the present report (fig. 1, loc. 1).

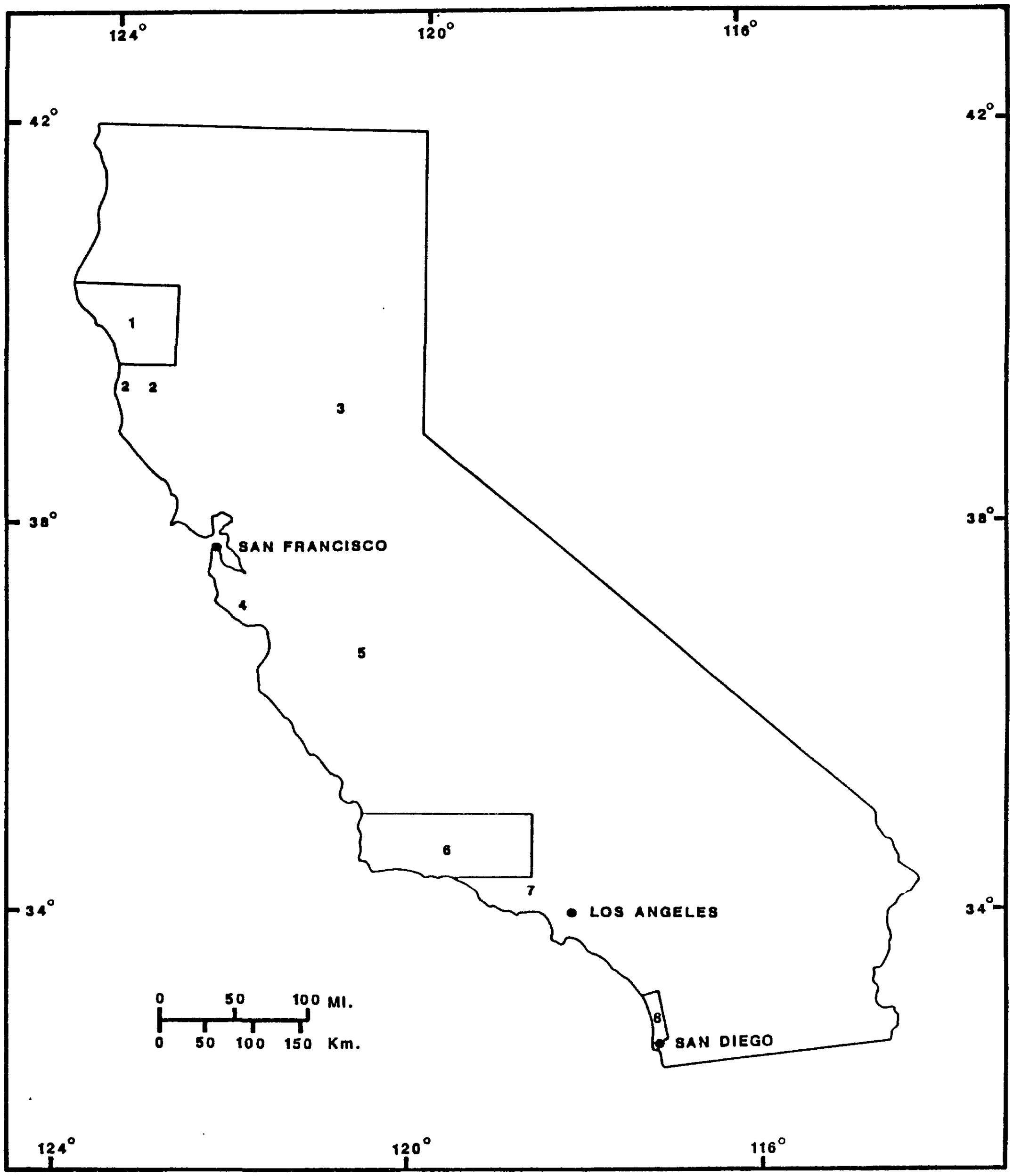

Figure 1. California localities and study areas mentioned in this report.

1. Area of figure 2 of this report.
2. Some sample localities of Evitt and Pierce (1975); most of their other sample localities are within the area of figure 2.
3. Sample locality of Leopold and Tschudy in Penny (1969).
4. Sample R4145 (late Eocene) of this report.
5. Sample locality of Drugg (1967).
6. Transverse Ranges study area of Frederiksen (1989).
7. Sample locality of Frederiksen (1983b).
8. Sampling area of Frederiksen (1983a).

In this report, pollen assemblages from central and northern California are compared with assemblages from southern California -- from the middle and upper Eocene of the Transverse Ranges and the middle Eocene of San Diego County (fig. 1, locs. 6, 8) -- that were described in detail mainly by Frederiksen (1983a; 1989).

Materials and Methods

Most of the samples providing the pollen assemblages described here were calcareous concretions of siltstone and mudstone. They were processed using normal palynological techniques of HCl; HF; short centrifugation with soapy water to remove fines; heavy liquid separation using a $ZnCl_2$ liquid of 1.45 s.g., which is necessary to separate palynomorphs from the abundant black woody particles; and screening on 10 µm sieves. The residues were mounted in glycerine jelly.

Sixty-eight Eocene and several Paleocene pollen taxa are mentioned in this report. The Eocene taxa and one of the Paleocene taxa are listed in table 1.

Paleocene(?) to Middle Eocene Pollen

Twenty-four Paleocene(?) to middle Eocene pollen samples from northern California have been studied for this report; they have been grouped to form 11 sample groups or assemblages (fig. 2; table 2). The samples were collected by R. J. McLaughlin and the writer. They are from the Yager and Coastal terranes which, together with the King Range terrane, make up the Coastal belt of the Franciscan Complex in the study region (Bachman and others, 1984; Blake and others, 1985).

Yager terrane

Pollen assemblages from the Yager terrane (fig. 2) are in the general area of most assemblages studied by Evitt and Pierce (1975), who provided Paleocene(?) and Eocene palynomorph (mainly dinoflagellate) ages for their samples.

Among the Yager terrane assemblages (table 2), R3712A may be the oldest (Paleocene?) because it contains *Lanagiopollis cribellata*, which does not range above the top of the Paleocene in the Gulf Coast (unpublished data of the writer). This sample also contains several other taxa that are common in the Paleocene, for example *Betulaepollenites* spp. and *Paraalnipollenites confusus*, which have a Paleocene to lower Eocene range in southern California. However, some middle Eocene samples from the Yager terrane also contain these Paleocene to early Eocene taxa, presumably as reworked

Table 1. Eocene pollen taxa discussed in this report (*Lanagiopollis cribellata*, which does not range higher than the Paleocene as far as known, is also included but is marked by an asterisk).

Gymnosperm pollen
- *Ephedra claricristata* Shakhmundes 1965
- *Ephedra exiguua* Frederiksen 1980
- *Ephedra fusiformis* Shakhmundes 1965
- "*Ephedripites*" *hungaricus* type[1]
- "*Ephedripites*" subgenus *Spiralipites* spp.

Diporate pollen
- *Psilodiporites* spp.

Triporate pollen
- *Momipites coryloides* group of Nichols (1973)[2]
- *Triatriopollenites intermedius* (Gladkova 1965) Kedves 1974
- *Triatriopollenites lubomirovae* (Gladkova 1965) Kedves 1974
- *Triatriopollenites triangulus* Frederiksen 1979
- *Triporopollenites* spp. (simple morphology)
- *Platycaryapollenites triplicatus* (Elsik 1974) Frederiksen & Christopher 1978
- *Plicatopollis magniorbicularis* Frederiksen 1983
- *Paraalnipollenites confusus* (Zaklinskaya 1963) Hills & Wallace 1969
- *Plicatopollis* spp.
- *Annutriporites subconvexus* Frederiksen 1983
- *Annutriporites rotundus* Frederiksen 1983
- *Corsinipollenites oculus-noctis* types[3]
- *Corsinipollenites cylindricus* Frederiksen 1989
- *Corsinipollenites warrenii* Frederiksen 1989
- *Corsinipollenites thiergartii* Frederiksen 1989
- *Ulmipollenites tricostatus* (Anderson 1960) Frederiksen 1980
- *Ulmipollenites krempii* (Anderson 1960) Frederiksen 1979
- *Ulmipollenites undulosus* Wolff 1934
- *Carya* <29 µm
- *Carya* >28 µm
- *Caryapollenites prodromus* group[4]
- *Subtriporopollenites* aff. *S. anulatus* Pflug & Thomson in Thomson & Pflug 1953
- *Proteacidites* spp.
- *Ruellia*? *laxa* (Frederiksen 1973) Frederiksen 1983
- *Rugulitriporites* spp.
- *Pistillipollenites macgregorii* Rouse 1962
- *Compositoipollenites* n. sp.

Table 1 (continued)

Multiporate pollen
- *Alnus vera* (Potonié 1931) Martin & Rouse 1966
- *Juglans* type
- *Pterocarya* type
- *Chenopodipollis* spp.

Monosulcate pollen
- *Longapertites* spp.

Tricolpate pollen
- *Cercidiphyllites* sp.
- *Cupuliferoidaepollenites* spp.
- *Quercoidites* spp.
- Tricolpate to tricolporate genus A of Frederiksen (1989)
- *Lonicerapollis* spp.
- *Salixipollenites* n. sp.

Tricolporate pollen
- *Eucommia* type
- *Siltaria* + *Cupuliferoipollenites*
- *Horniella brevicolpata* Frederiksen 1983
- *Ilexpollenites* spp.
- *Ailanthipites*? n. sp. (spheroidal)
- **Lanagiopollis cribellata* (Srivastava 1972) Frederiksen 1988
- *Lanagiopollis* sp. = *Alangiopollis* sp. 1 of Frederiksen (1983a)
- *Lanagiopollis* spp.
- *Cupanieidites* spp.
- *Insulapollenites* spp.
- *Intratriporopollenites* aff. and cf. *I. stavensis* Frederiksen 1980
- *Intratriporopollenites pseudinstructus* type[5]
- *Bombacacidites nanobrochatus* Frederiksen 1983
- *Bombacacidites* cf. *nanobrochatus*
- *Bombacacidites fereparilis* Frederiksen 1983
- *Bombacacidites* cf. *B. fereparilis*
- *Bombacacidites nanobrochatus-fereparilis* type
- *Bombacacidites reticulatus* Krutzsch 1961
- *Bombacacidites tilioides* Krutzsch 1970
- *Bombacacidites nacimientoensis* (Anderson 1960) Elsik 1968
- *Bombacacidites paulus* Frederiksen 1989
- *Bombacacidites* n. spp.
- *Sandiegopollis elkeae* Frederiksen 1983

Table 1 (continued)

Nudopollis terminalis (Pflug & Thomson in Thomson & Pflug 1953) Pflug 1953
Siberiapollis spp.

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[1]Typical species: "*Ephedripites*" *hungaricus* Nagy 1963
[2]Typical species: *Momipites coryloides* Wodehouse 1933
[3]Typical species: *Corsinipollenites oculus-noctis* (Thiergart 1940) Nakoman 1965
[4]Includes *Caryapollenites prodromus* Nichols & Ott 1978, *C. imparalis* Nichols & Ott 1978, and *C. wodehousei* Nichols & Ott 1978
[5]Typical species: *Intratriporopollenites pseudinstructus* Mai 1961

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specimens (tables 2, 3). It may also be significant that sample R3712A lacks typical Eocene species found in Eocene samples from the Yager terrane such as (fig. 3) *Annutriporites subconvexus, Corsinipollenites cylindricus*, and *Triatriopollenites* spp. However, the sample does contain *Triatriopollenites triangulus*, which ranges down into the Paleocene in the Atlantic Coastal Plain (Frederiksen, 1979).

The next oldest assemblage from the Yager terrane is R3425D, E (probably early Eocene in age), which contains the early Eocene species *Platycaryapollenites triplicatus* (fig. 3). It also has *Lanagiopollis* sp.; in southern California, thick-walled species of this genus have a restricted range from the upper part of the lower Eocene to the lowest part of the middle Eocene, and in the Gulf Coast, most thick-walled species of *Lanagiopollis* (that is, excluding the thin-walled Paleocene *L. cribellata*) range from the upper part of the lower Eocene to about the middle part of the middle Eocene.

Assemblage R3712B (probably early middle Eocene) is distinct among the Yager terrane assemblages because it contains *Triatriopollenites intermedius, T. triangulus*, and possible *T. lubomirovae*. *T. triangulus* has not previously been reported from California, but it ranges from upper Paleocene to middle Eocene in the Atlantic Coastal Plain (Frederiksen, 1979, 1984). In southern California, *Triatriopollenites lubomirovae* and *T. intermedius* are biostratigraphically important species that have range bases in the upper part of the lower Eocene and lowest part of the middle Eocene, respectively, and do not range up into rocks higher than lower middle Eocene (fig. 3).

The remaining assemblages from the Yager terrane (tentatively dated as middle middle Eocene to late middle

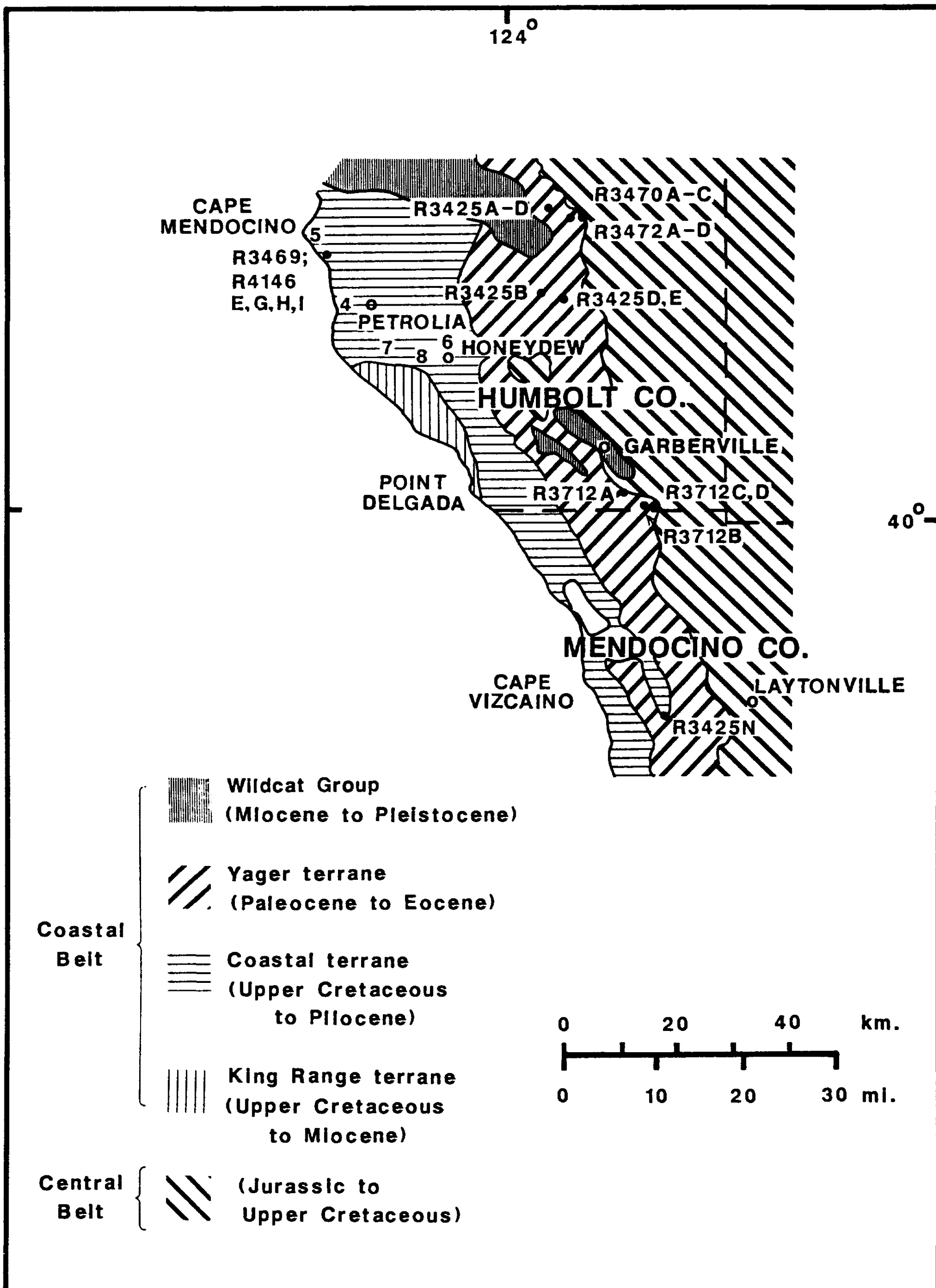

Figure 2. Map of parts of Humboldt and Mendocino Counties, California, showing Franciscan pollen localities studied for this report. Geology after Bachman and others (1984), Blake and others (1985), and Sliter and others (1986). Localities 4 and 5 are Eocene planktic foraminifer samples of Sliter and others (1986); localities 4, 6, 7, and 8 are Eocene dinoflagellate samples of Sliter and others (1986).

Table 2. Pollen taxon occurrences in samples from the Yager and Coastal terranes. Among assemblages from the Yager terrane, the three lowest assemblages shown are arranged in order of increasing apparent age downward, and the remaining five assemblages are arranged in geographic order north to south.

Yager terrane:
R3473A-D, field numbers NF85C 16-19, NE 1/4 sec. 11, T1N, R2E, Redcrest 7.5 min quadrangle.
R3472A-D, field numbers NF85C 12-15, NW 1/4 sec. 17, T1N, R3E, Bridgeville 7.5 min quadrangle.
R3470A-C, field numbers NF85C 1-3, NE 1/4 sec. 16, T1N, R3E, Bridgeville 7.5 min quadrangle.
R3425B, field number MT-4-83, SE 1/4 sec. 27, T1S, R2E, Weott 7.5 min quadrangle.
R3712C, D, field numbers MT-174-85, MT-175-85, E 1/2 sec. 22, T5S, R4E, Harris 7.5 min quadrangle.
R3712B, field number MT-168-85, W 1/2 sec. 21, T5S, R4E, Harris 7.5 min quadrangle.
R3425D, E, field numbers MT-35-83, MT-37-83, NW 1/4 sec. 32, T1S, R3E, Myers Flat 7.5 min quadrangle.
R3712A, field number MT-165-85, SW 1/4 sec. 17, T5S, R4E, Garberville 7.5 min quadrangle.

Coastal terrane:
R3469, field number S-85-133, SE 1/4 SE 1/4 sec. 3, T1S, R3W, Cape Mendocino 7.5 min quadrangle.
R4146E, G, H, I, field numbers NF87C-6A, 6C, 6D, 6E, same locality as R3469.
R3425N, field number MT-213-83, NW 1/4 sec. 19, T21N, R16W, Lincoln Ridge 7.5 min quadrangle.

Table 2.

Sample	Alnus vera	Annutriporites subconvexus	Aquilapollenites spp.	Betulaepollenites spp.	Bombacacidites cf. B. fereparilis	Bombacacidites cf. B. nanobrochatus	Bombacacidites fereparilis	Bombacacidites nanobrochatus	Bombacacidites paulus	Bombacacidites reticulatus	Carya <29 μm	Caryapollenites prodromus group	Cercidiphyllites spp.	Corollina spp.	Corsinipollenites cylindricus	Cupanieidites spp.	Cupuliferoidaepollenites spp.	Eucommiidites spp.	Insulapollenites spp.	Intratriporopollenites pseudinstructus type	Lanagiopollis cribellata	Lanagiopollis sp.	Lanagiopollis spp.	Longapertites spp.	Momipites coryloides group	Normapolles group (Cretaceous forms)	Nudopollis terminalis	Paraalnipollenites confusus	Pistillipollenites macgregorii	Platycaryapollenites triplicatus	Proteacidites + Siberiapollis	Subtriporopollenites aff. S. anulatus	Triatriopollenites intermedius	Triatriopollenites lubomirovae	Triatriopollenites triangulus	Triporopollenites marcaensis type	Triporopollenites spp. (simple morphology)	Ulmipollenites krempii	Ulmipollenites tricostatus	Ulmipollenites undulosus	Vitreisporites spp.	
R3473 A-D	X	X	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	YAGER TERRANE
R3472 A-D	X	X	X	X	.	X	.	.	.	.	?	X	.	.	X	.	.	X	X	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	X	.	.	.	X	
R3470 A-C	X	?	.	X	.	.	.	X	.	.	?	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	.	.	X	.	X	.	.	.	.	.	X	.	X	.	X	
R3425B	X	.	.	.	.	.	.	X	.	.	X	.	.	.	X	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	
R3712 C, D	X	?	.	.	X	.	.	X	.	.	X	.	.	.	?	.	X	.	.	X	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	
R3712B	X	X	.	X	.	.	X	X	.	.	X	X	X	X	.	.	.	.	.	X	.	.	.	.	X	X	.	X	X	.	X	X	X	?	X	.	X	.	.	X	X	
R3425 D, E	X	.	.	X	.	.	.	X	.	.	X	.	.	X	.	.	X	.	.	.	.	X	.	.	.	X	.	.	X	X	X	.	.	.	.	.	X	.	X	.	X	
R3712A	X	.	.	X	.	.	.	X	.	.	?	X	.	.	.	.	.	.	X	X	X	.	.	.	X	.	X	X	.	.	X	.	.	.	X	.	X	.	.	.	X	
R3469	X	X	.	X	.	X	X	.	X	.	.	X	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	X	.	X	.	.	COASTAL TERRANE
R4146E,G,H,I	X	X	X	X	.	.	.	X	.	.	X	X	.	X	.	X	.	X	X	X	.	.	X	?	X	.	?	.	X	.	X	.	.	.	.	X	X	.	X	.	X	
R3425N	X	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	?	X	.	X	.	.	.	.	.	X	X	.	.	.	

Table 3. Notable Late Cretaceous and Paleocene pollen taxa found as reworked specimens in Paleocene(?) to middle Eocene samples from the Yager and Coastal terranes (table 2).

Late Cretaceous
- *Aquilapollenites* spp.
- *Eucommiidites* spp.
- Normapolles group (Cretaceous forms)
- *Vitreisporites* spp.

Latest Cretaceous-Paleocene
- *Betulaepollenites* spp.
- *Corollina* spp.
- *Lanagiopollis cribellata* (Srivastava 1972) Frederiksen 1988
- *Paraalnipollenites confusus* (Zaklinskaya 1963) Hills & Wallace 1969
- *Triporopollenites marcaensis* Drugg 1967 type
- Some but not all specimens of *Proteacidites* + *Siberiapollis* and *Insulapollenites* spp.

Eocene) appear to be younger than early middle Eocene because they include *Annutriporites subconvexus* and *Corsinipollenites cylindricus*, both of which have their range bases in the lower part of the middle Eocene in southern California (fig. 3). None of these samples are upper Eocene because they do not contain abundant *Quercoidites* pollen (see remarks about this pollen genus in the discussion of the late Eocene sample from central California). They lack *Triatriopollenites*, apparently indicating that they are younger than early middle Eocene in age. The middle Eocene samples are generally similar to coeval samples from southern California, although the preservation of pollen is not good enough to enable differentiation of new species that might be present in the northern California samples but not in those from southern California.

If palynomorph dates of samples R3712A (Paleocene?), R3712B (probably early middle Eocene), and R3712C, D (probably middle middle Eocene to late middle Eocene) are correct, then the dip of strata in the R3712 area (fig. 2) apparently is to the east.

Coastal terrane

Samples R3469 and R4146E, G, H, and I are from the Cape Mendocino area (fig. 2) and lie between localities 4 and 5 of Sliter and others (1986), which contained planktic foraminifers of middle Eocene and late middle Eocene ages,

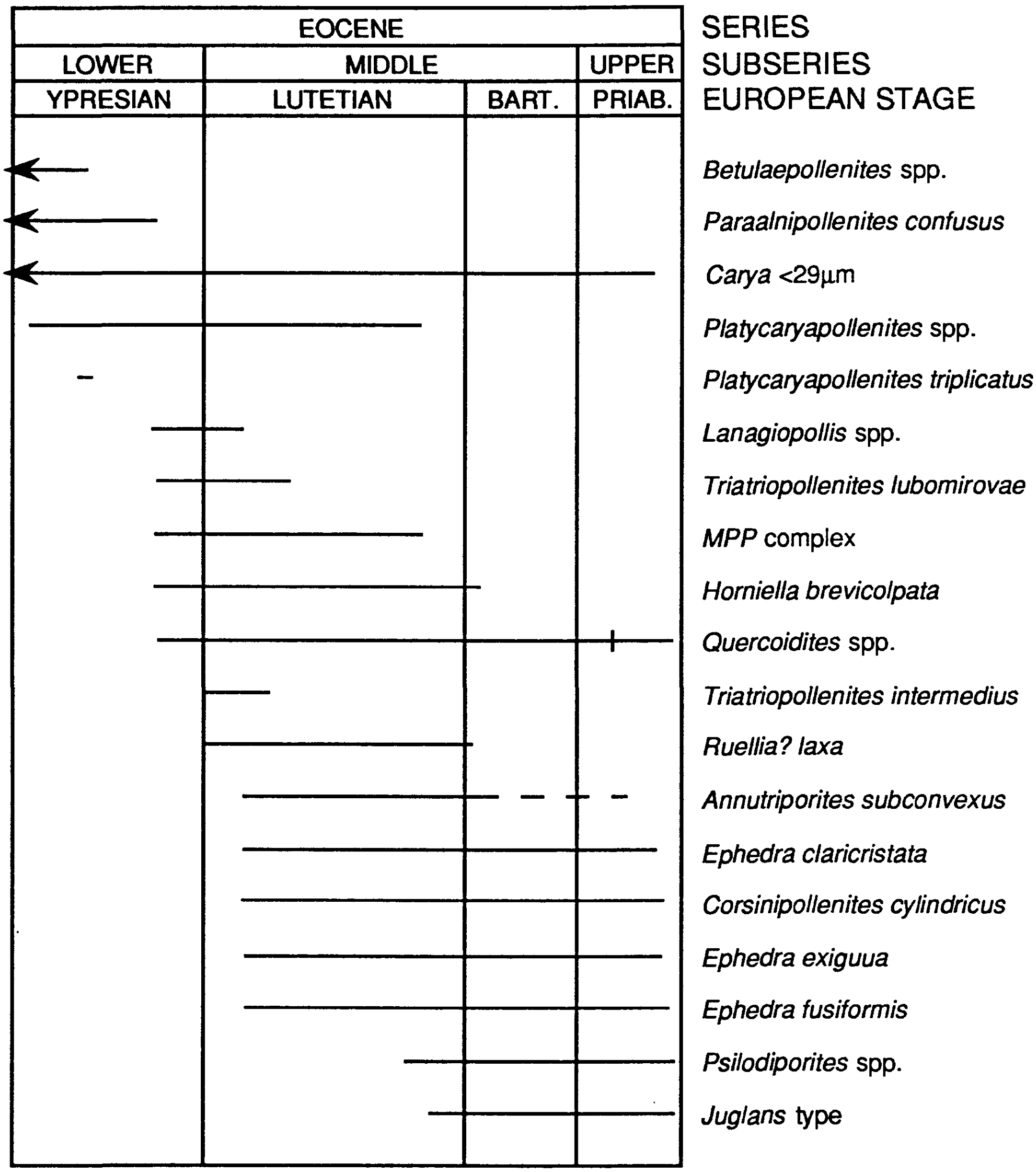

Figure 3. Ranges in southern California (Frederiksen, 1989) of stratigraphically important pollen taxa discussed in this report. The cross-bar in the range line for *Quercoidites* spp. shows the lowest occurrence of abundant specimens of this taxon.

respectively. Also in the vicinity are four samples that contained middle Eocene dinoflagellates (Sliter and others, 1986) (fig. 2).

Assemblages R3469 and R4146E, G, H, and I are similar to the pollen assemblages from the Yager terrane that were dated as probably middle middle Eocene to late middle Eocene; they include *Annutriporites subconvexus* and *Corsinipollenites cylindricus*, and they lack the *Ephedra claricristata* group, *Triatriopollenites*, and abundant *Quercoidites* pollen. At least in the R4146 samples, *Carya* <29 μm pollen is a common constituent, whereas this pollen form is relatively uncommon above the lower part of the middle Eocene in southern California (see discussion of *Carya* and related pollen later in the report).

Sample R3425N, from west of Laytonville, Mendocino County, has a low-diversity assemblage that could be late Paleocene or Eocene in age.

Reworked pollen

Pollen interpreted as reworked is found in most if not all assemblages from the Yager and Coastal terranes studied for this report. Typical examples (from table 2) are listed in table 3.

The presence of *Aquilapollenites* spp. in the samples suggests reworking of sediments from easterly rather than westerly sources because this genus has not been found in allochthonous terranes, originating at low latitudes, which are now mainly located in western parts of the Pacific States and Provinces of North America (Frederiksen, 1987).

Late Eocene Pollen

Sample R4145 (field no. NF87C-3) is from the prominent concretion bed just below the top of the Twobar Shale Member of the San Lorenzo Formation on the San Lorenzo River near Riverside Grove, Big Basin 7.5 min quadrangle, Santa Cruz County, California (fig. 1, loc. 4; Brabb and others, 1977, p. 24, 30). This sample is from strata assigned to the *Discoaster barbadiensis* calcareous nannofossil zone (Warren and Newell, 1980); the sample is no older than the P16 planktic foraminiferal zone (Poore and Brabb, 1977) and therefore is from the upper half of the Priabonian Stage (Upper Eocene Subseries) (Berggren and others, 1985). Thus, the sample is correlative with some part of the interval that includes (in ascending order) the upper part of the Sacate Formation (of Kelley, 1943), the Gaviota Formation (of Effinger, 1935, as used by Dibblee, 1950), and the lower part of the Alegria Formation (of Dibblee, 1950), in the western

Transverse Ranges of southern California (ages of these units determined by Warren and Newell, 1980). R4145 is the only well preserved late Eocene pollen assemblage from central or northern California that I know of; thus, it is important both biostratigraphically and biogeographically.

In table 4, the pollen assemblage from the Twobar Shale Member of central California is compared with three groups of late Eocene assemblages from southern California. Pollen occurrence data for the southern California samples are mainly from Frederiksen (1989), supplemented by additional late Eocene data from the Standard Oil Company Gerber no. 1 well, Santa Barbara County, Cal. (see Frederiksen, 1985). Taxon occurrences in the three comparison sample groups of table 4 are based on observed occurrences in each sample modified by the use of the range-through method of Cheetham and Deboo (1963); this method assumes that each taxon actually occurs in every sample from its lowest observed occurrence to its highest, in order to minimize ecological influences on individual sample assemblages.

There is a considerable similarity between the assemblage from the Twobar Shale Member and the southern California assemblages particularly from the upper part of the Sacate Formation and the Gaviota Formation. The lower part of the Alegria Formation is represented by only one sample, and thus the true nature of the Alegria pollen assemblages is not well known.

Late Eocene time was very brief (only 3.4 m.y. according to Berggren and others, 1985). Very few pollen taxa had first occurrences in latest middle Eocene to late Eocene time in either the Gulf Coast (Frederiksen, 1988) or southern California (Frederiksen, 1989); apparently for climatic reasons, little plant evolution or immigration occurred during this time span in these two regions. Therefore, there are few if any known pollen taxa in sample R4145 that are restricted to the late Eocene. However, *Psilodiporites* spp. and *Juglans* type are typical at least of the latter half of Eocene time in southern California (fig. 3); these taxa had their first occurrences in mid-Eocene time in that region. The lack of taxa such as *Platycaryapollenites* spp., *Momipites-Plicatopollis-Platycaryapollenites* complex, *Horniella brevicolpata*, and *Ruellia? laxa* (fig. 3) in R4145 is also significant; these taxa are not known to range above the middle part of the middle Eocene in southern California.

Biostratigraphically, the most important aspect of the Twobar Shale Member assemblage is a feature that is not obvious from table 4, and that is the abundance of *Quercoidites* spp. pollen in the sample from this unit. In southern California, specimens of this pollen genus (undoubtedly representing the subfamily Quercoideae - oaks -

Table 4. Pollen taxa in sample R4145 (Twobar Shale Member of the San Lorenzo Formation) from Santa Cruz County and in the upper part of the Sacate Formation (of Kelley, 1943), the Gaviota Formation (of Effinger, 1935, as used by Dibblee, 1950), and the lower part of the Alegria Formation (of Dibblee, 1950) of the western Transverse Ranges, southern California.

Taxon	R4145 (CENTRAL CAL.)	Low. Alegria (SOUTHERN CAL.)	Gaviota (SOUTHERN CAL.)	Up. Sacate (SOUTHERN CAL.)
"Ephedripites" hungaricus type	X	?	X	X
"Ephedripites" subgenus Spiralipites spp.	X	.	X	X
Ailanthipites? n. sp. (spheroidal)	X	.	.	.
Alnus vera	X	.	X	X
Annutriporites rotundus	.	.	X	X
Annutriporites subconvexus	X	.	X	X
Bombacacidites cf. B. fereparilis	.	.	X	X
Bombacacidites fereparilis	.	X	X	X
Bombacacidites n. spp.	X	.	.	.
Bombacacidites nacimientoensis	X	.	.	X
Bombacacidites nanobrochatus	X	X	X	X
Bombacacidites nanobrochatus-fereparilis type	.	X	X	X
Bombacacidites paulus	X	X	X	X
Bombacacidites tilioides	.	.	.	X
Carya <29 µm	.	.	X	X
Carya >28 µm	X	.	X	.
Chenopodipollis spp.	X	.	.	.
Compositoipollenites n. sp.	X	.	.	.
Corsinipollenites cylindricus	X	.	X	X
Corsinipollenites oculus-noctis types	X	X	X	X
Corsinipollenites thiergartii	.	.	X	X
Corsinipollenites warrenii	X	.	.	.
Ephedra claricristata	X	.	X	X
Ephedra exiguua	.	.	X	X
Ephedra fusiformis	X	X	X	X
Eucommia type	.	?	.	X
Ilexpollenites spp.	.	.	X	X
Intratriporopollenites aff. and cf. I. stavensis	X	.	X	X
Juglans type	X	.	X	X
Lonicerapollis spp.	.	X	X	X
Momipites coryloides group	.	.	X	X
Plicatopollis magniorbicularis	.	.	.	X
Plicatopollis spp.	.	X	X	X
Psilodiporites spp.	X	X	X	X
Pterocarya type	.	.	X	X
Quercoidites spp.	X	X	X	X
Rugulitriporites spp.	.	.	X	X
Salixipollenites n. sp.	X	.	.	.
Sandiegopollis elkeae	.	.	X	.
Siltaria + Cupuliferoipollenites	.	.	X	X
Tricolpate to tricolporate genus A	X	.	X	X
Ulmipollenites krempii	X	.	.	X
Ulmipollenites tricostatus	.	.	.	X
Ulmipollenites undulosus	X	X	X	X

of the family Fagaceae) first became abundant in the upper part of the Sacate Formation, in rocks of approximately middle late Eocene age (fig. 3). In contrast, Quercoideae pollen is abundant throughout the Eocene of the Gulf Coast (Tschudy, 1973).

Some differences exist between the assemblage from R4145 and the late Eocene assemblages from southern California that probably represent biogeographic differences between the two regions. *Ailanthipites*(?) n. sp. (spheroidal), *Bombacacidites* n. spp. (several species), *Compositoi-pollenites* n. sp., and *Salixipollenites* n. sp. are listed in table 4 as examples of taxa that occur in R4145 but have not been found in southern California. The diversity of the pollen genus *Bombacacidites* (representing the important, mainly tropical families Bombacaceae and Sterculiaceae) is approximately the same in R4145, from central California, as in upper Eocene units of southern California; thus, the late Eocene climate of central California was not obviously cooler than in southern California. *Chenopodipollis* (probably produced by herbs of the family Chenopodiaceae) is abundant in sample R4145, in contrast to late Eocene assemblages from southern California where it is rare to absent; however, it is not clear whether the abundance of *Chenopodipollis* pollen in R4145 is due more to ecological or biogeographical/climatic effects.

Remarks on Pollen Morphology and Distribution

Triporopollenites spp. (simple morphology)

Most of the Paleocene(?) and Eocene pollen assemblages from northern California include a taxon listed in this report as "*Triporopollenites* spp. (simple morphology)." These grains lack a thickening of the exine at the apertures. Possible atria or vestibula are not seen, but this is because the thin nexine in these specimens is probably missing. Therefore, although the grains appear to belong to *Triporopollenites*, some of the specimens in this category probably belong to the *Momipites coryloides* group; others may possibly belong to *Triatriopollenites* or even to *Trivestibulopollenites*.

Ephedra claricristata group

An interesting if ambiguous aspect of the middle middle Eocene to late middle Eocene assemblages from northern California is that all of them appear to lack the *Ephedra claricristata* group (*E. claricristata, E. exiguua, E. fusiformis*); in southern California, specimens of the *E.*

claricristata group are common in most Eocene samples above the range base of the group in the lowest part of the middle Eocene (fig. 3). Specimens of the *Ephedra claricristata* group are robust and easy to identify; therefore, they are not likely to have been entirely missing or overlooked in the northern California samples because of poor preservation. In contrast, specimens of *Ephedra* are common and diverse in the late Eocene sample R4145.

Carya and Related Pollen

One of the most interesting pollen groups in the samples from central and northern California is composed of pollen referred to the modern genus *Carya* (Juglandaceae; hickory and pecan) and to *Caryapollenites*, which represents pollen probably of extinct genera that were genetically related to *Carya*.

The biostratigraphic significance of *Carya* spp. in Eocene deposits of California is difficult to evaluate because specimens of this genus are typically sparse, at least in southern California, in contrast to the Gulf Coast where they are common more or less throughout the Eocene. In the Gulf Coast, pollen of this genus can be differentiated into two groups based on a size difference; the two groups overlap stratigraphically (Tschudy, 1973): *Carya* <29 µm ranges from middle Paleocene to uppermost Lutetian, whereas *Carya* >28 µm has its range base in the lowermost Lutetian and still exists today (Lutetian = lower middle Eocene) (Frederiksen, 1988). However, in southern California, *Carya* <29 µm ranges up much higher than in the Gulf Coast, at least into the upper Eocene (Frederiksen, 1989). Furthermore, in southern California, *Carya* >28 µm has been found in only one sample, from the upper part of the Gaviota Formation (upper Eocene; in the Gerber no. 1 well mentioned previously) as well as in the upper Eocene sample R4145 from central California discussed in this report. In southern California samples, *Carya* <29 µm is not abundant above the lowest part of the middle Eocene; however, in the northern California samples reported here, this pollen type is common in some samples that are probably younger than earliest middle Eocene in age.

Unfortunately, I did not differentiate between *Carya* pollen and the *Caryapollenites prodromus* group in my studies of the Eocene in southern California (Frederiksen, 1983a, b, 1989) or in the Gulf Coast (Frederiksen, 1988); therefore, I have no information about the range top of the *Caryapollenites prodromus* group in those regions. The *Caryapollenites prodromus* group was found in about half the assemblages examined from northern California, and most of these seem to be younger than earliest Eocene in age.

In the Western Interior, *Carya* and the *Caryapollenites prodromus* group are much more abundant in Paleocene than in Eocene samples (Nichols and Ott, 1978; Wingate, 1983; Nichols, 1987; Pocknall, 1987). Therefore, the range top of the *Caryapollenites prodromus* group in the Western Interior is poorly known; however, it does range at least into the lower part of the middle Eocene (Leopold, 1974).

In summary, the Eocene stratigraphic distributions of pollen species and species groups within the genera *Carya* and *Caryapollenites* are not well known in California, the Western Interior, or (for *Caryapollenites*) in the Gulf Coast. However, distinct differences appear to exist in the distributions and relative frequencies of these taxa in California as opposed to the Gulf Coast and the Western Interior, and there may be some differences at least in relative frequencies of these pollen types in northern vs. southern California.

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