Paleogene accretion of Upper Cretaceous oceanic limestone in northern California

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ABSTRACT

Blocks of pelagic limestone, tectonically incorporated into coastal terrane melange, contain planktonic foraminifers of early Campanian to middle Maestrichtian age (82–69 Ma) typical of low latitudes between 20°N and 20°S. Carbonate concretions from the sheared terrigenous matrix of the melange yield temperate, middle-latitude planktonic foraminifers and dinoflagellates of middle to late Eocene age (49–41 Ma). The pelagic limestone and the basaltic substrate presumably formed on the eastern flank of the Pacific-Farallon spreading ridge in a low-latitude zone of high productivity and migrated northward on the Farallon plate until about 40 Ma when they initially encountered terrigenous turbidites north of lat. 30°N. Northward translation and final accretion were completed by about 25 Ma.

INTRODUCTION

The Franciscan Complex of northern California records an involved history of tectonic processes that include subduction-related accretion, oblique underthrusting, tectonic wedging, and the northward translation of rock assemblages (Blake et al., 1984, 1985; McLaughlin and Ohlin, 1984; Wentworth et al., 1984). Critical to the understanding of the timing of these various tectonic events is the biostratigraphic dating and correlation of the rock assemblages. Paleontologic analysis also plays a key role in deciphering the paleolatitudinal history for individual terranes. Oceanic rocks within the Franciscan Complex—both pelagic foraminiferal limestone (Sliter, 1984) and radiolarian chert (Murchey and Jones, 1984; Pessagno et al., 1984)—have recently undergone paleontologic scrutiny. Here we report on the age and tectonic history of oceanic and terrigenous rocks of the coastal belt near Cape

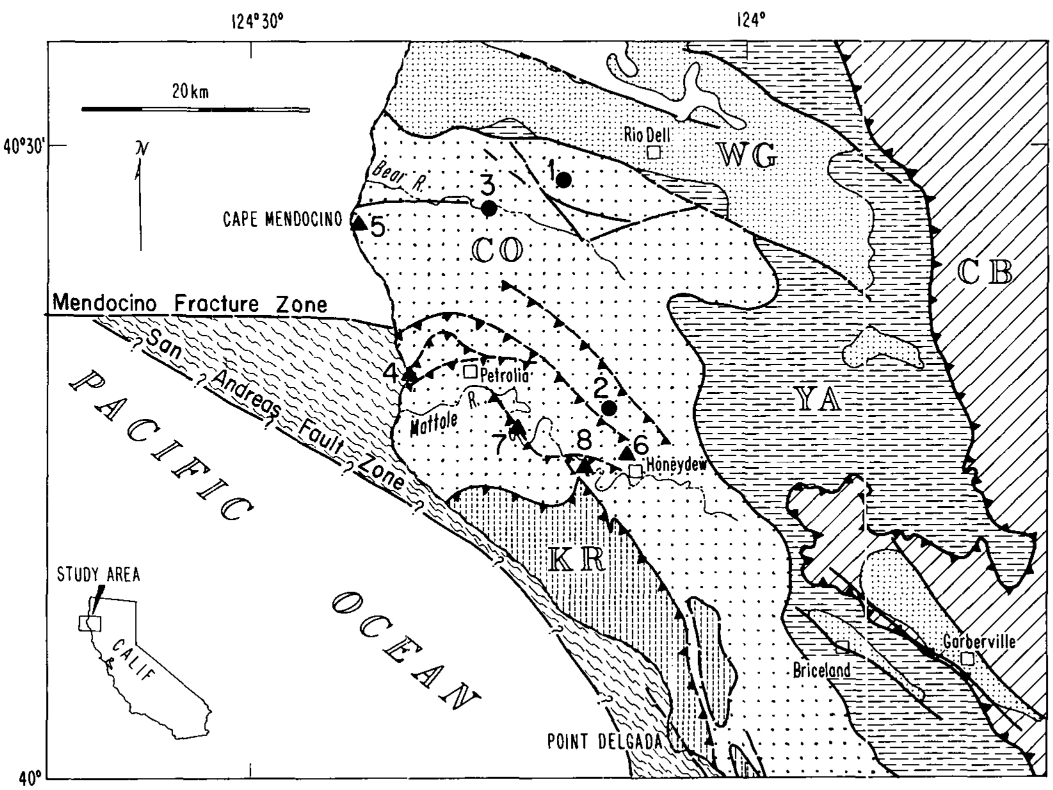

Figure 1. Geologic map of Franciscan terranes and autochthonous Wildcat Group near Cape Mendocino, northern California. CO: coastal terrane; KR: King Range terrane; YA: Yager terrane; CB: central belt terranes; WG: Wildcat Group. Numbers 1 to 8 indicate fossil localities discussed in text. Circles: limestone localities; triangles: melange matrix localities. Geology after unpublished maps of R. J. McLaughlin, S. Ellen, M. C. Blake, Jr., and A. S. Jayko. Teeth on upper plates of thrusts. Contacts and faults dashed where inferred.

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Mendocino, California (Fig. 1). Our new data shed light on the timing of accretion, the site of deposition of the oceanic rocks, and the latitude of collision.

TECTONIC SETTING

The Franciscan Complex east of Cape Mendocino consists of several fault-bounded tectonostratigraphic terranes grouped into two distinctive belts, the coastal belt and the central belt (Irwin, 1960). We focus here on the coastal terrane (Fig. 1). The coastal terrane, the King Range terrane, and the Yager terrane represent the three major mappable, partially coeval, and tectonically juxtaposed structural entities that make up the coastal belt.

King Range Terrane

The King Range terrane, of Late Cretaceous to middle Miocene age (McLaughlin et al., 1982), probably represents lower-slope and/or trench-slope deposits. It consists of two fault-bounded units: (1) a southwestern unit of Upper Cretaceous basalt flows and flow breccias, overlain and intercalated with folded sandstone and melange containing at least one large block of blueschist; and (2) a northeastern unit of Paleogene(?) to middle Miocene age, of highly folded sandstone and argillite turbidites with rare blocks of pelagic limestone, basalt, and basalt-chert. The King Range terrane is bounded to the southwest by the San Andreas fault zone, and to the northeast by a southwest-dipping Neogene thrust that has uplifted and obducted the King Range terrane eastward over the adjacent coastal terrane (McLaughlin et al., 1982).

Coastal Terrane

Rocks of the coastal terrane range in age from Late Cretaceous (Campanian) to late Eocene. Regionally, the terrane is composed dominantly of broken formation, but is mostly melange in the area adjacent to Cape Mendocino. These sedimentary rocks are interpreted to have been deposited in a slope or trench-slope setting along the continental margin, in part as submarine fan deposits and canyon fill. Enclosed by the melange are rare blocks of basalt, pelagic limestone, or even more rarely, high-grade blueschist that occurs adjacent to the boundary with the King Range terrane (McLaughlin et al., 1982).

Yager Terrane

The Yager terrane is a broken, highly folded unit of Paleocene(?) to late Eocene age. It consists typically of thin- to medium-bedded flysch with locally prominent, thick lenses of arkosic to feldspathic sandstone. The Yager terrane, interpreted as a channeled-slope-basin or trench-slope-basin deposit by Underwood (1983), structurally overlies more highly deformed rocks of the coastal terrane. The Yager terrane differs from the coastal terrane in being more stratally intact and in containing no exotic, tectonically incorporated rocks.

Central Belt Terranes

The Franciscan central belt, like the coastal belt, consists of numerous dismembered terranes. However, the terranes of the central belt are more diverse in age, lithology, and metamorphic grade. These terranes range in age from Middle Jurassic to early Paleogene and are metamorphosed from zeolite to blueschist grades. Regionally, the central belt overlies the Yager and coastal terranes along the east-dipping coastal belt thrust (Jones et al., 1978).

AGE OF THE OCEANIC LIMESTONE

Three exposures of limestone within the coastal terrane near Cape Mendocino (Fig. 1) provide an age range of early Campanian to middle Maestrichtian (about 82 to 69 Ma) based on planktonic foraminifers studied in thin section. All three of these localities are within melange. The Hackettsville and Parkhurst Ridge localities consist of larger, relatively intact basalt-limestone blocks within the melange. The limestone locality at Bear River, however, is not in direct contact with basalt, although blocks of pillowed basalt are found nearby.

The Hackettsville locality (loc. 1), along the west side of Howe Creek, is a sheared lenticular block of pillow basalt overlain by red-brown and light-gray micritic pelagic limestone. The sheared and heavily veined pelagic limestone contains foraminifers assigned to the *Gansserina gansseri* Zone of middle Maestrichtian age (71–69 Ma, Fig. 2). Species present include *Globotruncana arca, G. linneiana, G. rosetta, Globotruncanita stuartiformis, G. stuarti, Gansserina gansseri* group, and *Rosita walfischensis* s.l., among others (Fig. 3).

The Parkhurst Ridge locality (loc. 2), near Honeydew, is a large, roughly lenticular block about 3 km long composed of diabase, basalt-diabase breccia, and vesicular, pillowed, alkalic basalt flows, overlain by at least 12 m of synclinally folded predominantly red-brown to light-green, locally laminated, micritic pelagic limestone. Planktonic foraminifers from the limestone range in age from early Campanian to early Maestrichtian (from the *Globotruncanita elevata* Zone to at least the *Globotruncana falsostuarti* Zone, 82–72 Ma, Fig. 2). Species present include *Globotruncana arca, G. ventricosa, Globotruncanita elevata, G. stuartiformis, G. stuarti,* and *Globotruncanella havanensis,* among others.

Along the Bear River on the north side of Southmayd Ridge (loc. 3), blocks of light-gray, heavily veined micritic limestone yield planktonic foraminifers assigned to the *Globotruncana ventricosa* Zone of late Campanian age (78–75 Ma, Fig. 2). Species present include *Globotruncana arca, G. bulloides, G. linneiana, G. ventricosa,* and *Globotruncanita stuartiformis,* among others.

AGE OF THE TERRIGENOUS MELANGE MATRIX

Planktonic foraminifers and dinoflagellates preserved in carbonate concretions in the sheared argillite matrix of the coastal terrane

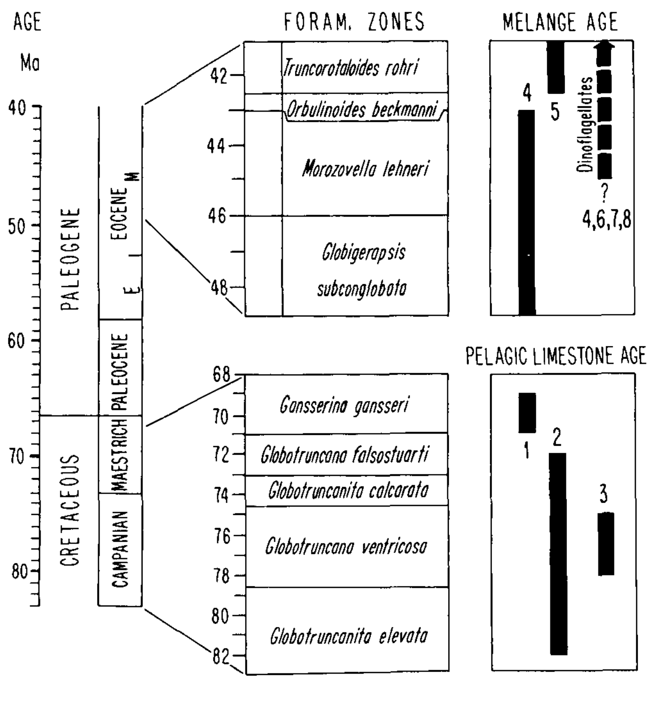

Figure 2. Age range of oceanic and terrigenous rocks from Franciscan coastal terrane near Cape Mendocino, dated by planktonic foraminifers and dinoflagellates. Numbers refer to localities discussed in text. Geologic time scale after Berggren et al. (1986) and Harland et al. (1982).

melange at six localities near Cape Mendocino (Fig. 1) range in age from middle to late Eocene. Thus, the melange matrix is much younger than the enclosed blocks of pelagic limestone. Planktonic foraminifers studied in thin section range from middle to late middle Eocene age (McLaughlin et al., 1984). Faunas in concretions from melange adjacent to the limestone at Hackettsville (loc. 1) and from near the mouth of the Mattole River (loc. 4) are middle Eocene in age. These foraminiferal assemblages are referred to the *Globigerapsis subconglobatus–Morozovella lehneri* Zones (Fig. 2; P11-12, 49 to 43 Ma) on the basis of the presence of *Acarinina bullbrokki, Globorotalia cerroazulensis* s.l., *Subbotina eocaena, S. linaperta, Globigerinatheka subconglobata* and *Pseudohastigerina* sp. A late middle Eocene age *Truncorotaloides rohri* Zone (P14, about 42.5 to 41 Ma), is indicated for concretions in melange at Cape Mendocino north of Ocean House (loc. 5) on the basis of the presence of a similar assemblage and *Globigerina officinalis* and *Truncorotaloides collacteus.*

Dinoflagellates from the concretions are also Eocene in age. Assemblages from locality 4 and in concretions from the Upper North Fork of the Mattole River (loc. 6), about 4 km south of Parkhurst Ridge, most likely are middle to late Eocene in age on the basis of the presence of species such as *Deflandrea phosphoritica, Areospheridium diktyoplokus, Cordosphaeridium* sp., *Lejeunecysta* sp., *Rhombodinium* sp., *Turbiosphaera* sp., and *Wetzeliella* sp. A probable Eocene age is assigned to melange at locality 7 on the Mattole Road 1 km west of Arthur W. Way County Park and at locality 8 from the Mattole River at the Upper Mattole School by the occurrence of *Polysphaeridium* sp. cf. *P. zoharyi* and poorly preserved *Areosphaeridium diktyoplokus.*

These dinoflagellate assemblages are similar in age and fossil content to Eocene assemblages described previously from the coastal belt to the south between Briceland and Willits, and from the Yager terrane to the east (Evitt and Pierce, 1975).

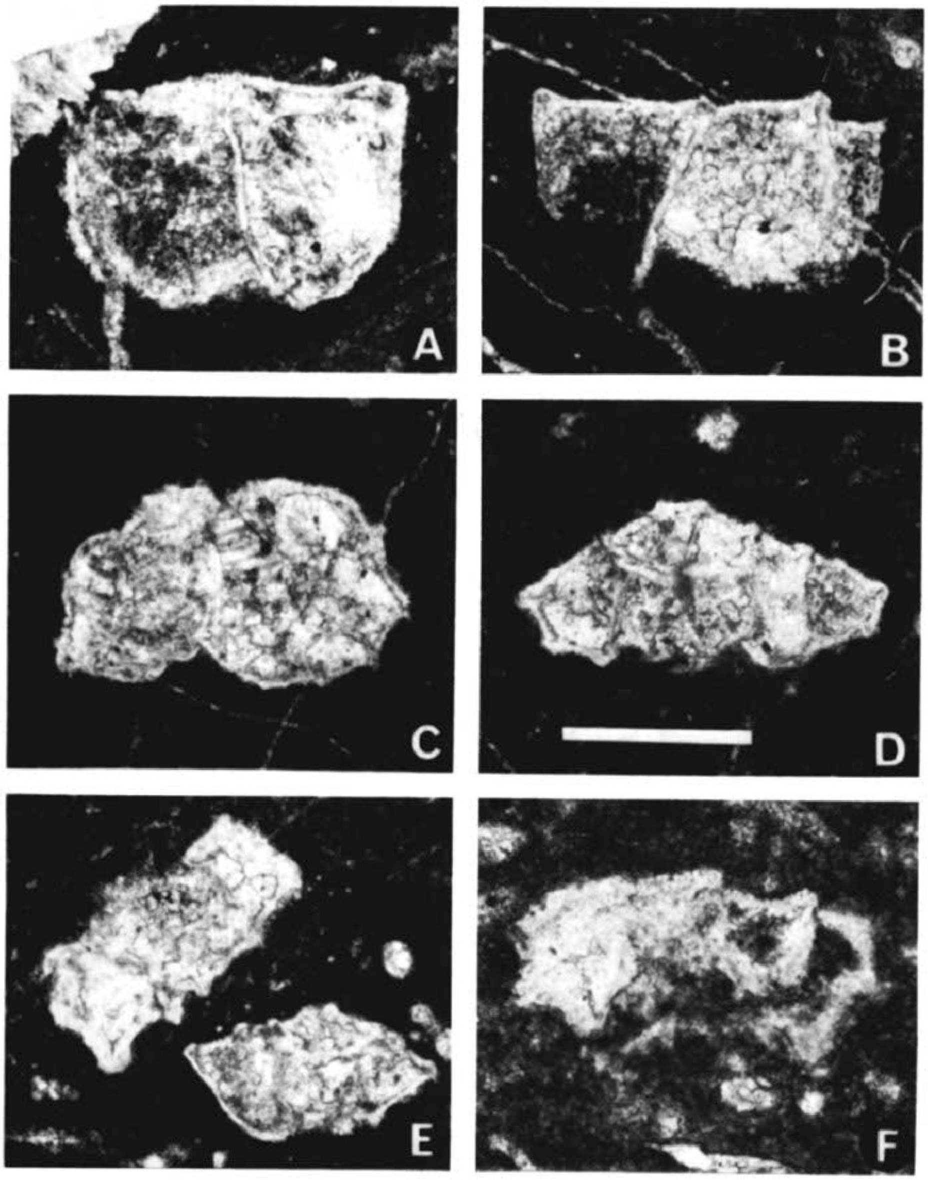

Figure 3. Middle Maestrichtian planktonic foraminifers from pelagic limestone near Hackettsville, northern California (loc. 1). A, B: *Gansserina gansseri* group; C: *Rosita* sp. cf. *R. walfischensis* (Todd); D: *Globotruncana arca* Cushman; E: *Globotruncana linneiana* (d'Orbigny) on left, *Globotruncanita stuartiformis* (Dalbiez) on right; F: *Globotruncana ventricosa* White. Scale bar in D (for all photos) = 300 μm.

TECTONIC HISTORY

The present paleontologic data indicate that pelagic limestone of Cretaceous age derived from an oceanic plate (probably Farallon) was tectonically mixed with terrigenous sediments of Eocene age derived from the North American margin sometime after 42 Ma. This mixing, which we suggest resulted from the collision of a Cretaceous near-ridge volcanic edifice with the North American margin, followed migration of the oceanic elements on one or more oceanic plates across the eastern North Pacific Ocean. The depositional overlap of postaccretionary Neogene deposits of the Humboldt basin across the Yager and coastal terranes and the Franciscan central belt requires that these tectonostratigraphic terranes were assembled at their present latitude by early to middle Miocene time. Thus, final accretion of the coastal terrane may have occurred as late as the latest Oligocene at about 24 Ma (McLaughlin et al., 1984).

Of particular interest to the displacement history of the oceanic plates is the inferred site of deposition of the oceanic limestone and the latitudinal limits of interaction with the American continent. Several lines of evidence indicate a low-latitude source for the oceanic deposits: (1) The species composition and diversity of planktonic foraminifers from the oceanic limestone are very similar to Cretaceous assemblages previously described from low-latitude, Tethyan environments in the Pacific Ocean (Sliter, 1972, 1984). The presence of species such as *Gansserina gansseri* s.l. and *Rosita walfischensis* s.l. suggests depositional limits of 20°N–20°S. (2) Paleomagnetic interpretation of the Parkhurst Ridge Limestone (loc. 2) suggests a depositional paleolatitude between 20° and 28°N (Harbert et al., 1984). These reconstructions require between 2500 and 3300 km of northward convergence at a rate of 6–10 cm/yr if deposited at 20°N or 5–8 cm/yr if deposited at 28°N. (3) The limestone is typical of deep-sea pelagic carbonates deposited beneath or adjacent to the equatorial zone of high productivity (Cook and Egbert, 1983). Coeval Late Cretaceous limestone in the North Pacific is known from the Mid-Pacific Mountains (Larson, Moberly et al., 1975), the Magellan Plateau (Winterer, Ewing et al., 1973), and the Line Islands (Winterer, Ewing et al., 1973; Schlanger, Jackson et al., 1976).

Evidence for the latitude of collision of the oceanic elements with North America comes from the planktonic foraminifers in terrigenous sedimentary rocks of the coastal terrane melange. Deposition of the middle Eocene assemblages from the carbonate concretions most likely occurred in a temperate middle latitude. This interpretation is based on the abundance of *Globigerina officinalis,* a temperate form, and the absence of keeled subtropical to tropical forms. Depositional latitudes would thus range from about 30°N to the present latitude of Cape Mendocino near 40°N.

The paleontologic, paleomagnetic, and lithologic data support a low-latitude origin for pelagic limestones of the Franciscan coastal terrane. We propose that these oceanic pelagic limestones were deposited on Farallon plate seamounts, plateaus, and ridges originally formed at or near the Pacific-Farallon spreading center and are analogous to those now seen only in the western Pacific. This interpretation is supported by the tholeiitic to alkalic compositions of the basaltic substrates of the limestones, which are typical for seamounts. The data suggest that these east Pacific remnants of seamounts, plateaus, and ridges migrated northward on the Farallon plate until about 40 Ma. The oceanic plate then encountered terrigenous turbidites, north of 30°N, that were derived from the North American margin. Although at present there is no direct evidence for earlier encounters of the coastal terrane oceanic limestones with the continental margin, we do not rule out this possibility. During the initial interaction at about 40 Ma, slabs of oceanic rocks were sliced off the Farallon plate and mixed with the terrigenous American plate-derived components. This "collage" was then translated northward along the continental margin and accreted later at the present latitude.

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