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CONTRASTING MEGAFAUNAL AND SEDIMENTARY RECORDS FROM OPPOSITE ENDS OF THE GULF OF CALIFORNIA: IMPLICATIONS FOR INTERPRETING ITS TERTIARY HISTORY

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Introduction

Distribution patterns of marine mollusks supported by radiometric and sedimentological data indicate important differences between Tertiary records in the northern and southern parts of the Gulf of California. Published geophysical reconstructions have focused on the mouth of the Gulf and assumed seawater entered the Gulf at 4 - 6 Ma (Larson, 1972; Johnson and others, 1983; Curray and Moore, 1984; Hagstrum and others, 1987), about the age of marine microfossils at the Tres Marias Islands. A record of a more ancient gulf extending through the Cabo Trough correlates in part with thicker sections in the northern Gulf, including the northern and southern Salton Trough.

Results of megafaunal studies indicate that by 13 Ma seawater extended as far as the northern Salton Trough (Figure 1). Time represented at the mouth of the Gulf by unconformities and 1.5 km of deposits is recorded in up to 5 km of sediments in the north. There has been 8 million years more time than is generally assumed for the evolution of the Gulf of California. In places, fault movement dated on the basis of displaced marine sediments incorrectly regarded as Pliocene may actually have occurred as early as late middle Miocene.

Sedimentary records and structural details are complex and different at opposite ends of the Gulf. At the north end, in the central Salton Trough, Tertiary sediments are about 5 km thick, but along the trough's southwestern margin they are only 0-1 km thick. Basement consists of metamorphic and volcanic rocks and even old alluvial deposits (Kidwell, 1988). At the south end, in the Cabo Trough, Tertiary marine sediments measure 1 - 1.3 km, overlying nonmarine Coyote Redbeds and granitic basement (McCloy, 1984). In the Tres Marias Islands Tertiary marine rocks on Maria Madre Island have a combined thickness of 1,145 m, ranging in age from late Miocene to late Pliocene (Carreño, 1985; McCloy and others, 1988). Unconformable on Cretacous granite and Tertiary (?) volcanic basement rocks, the Maria Madre deposits are older than those penetrated at Deep Sea Drilling Project sites in the area.

Tectonic events in the evolution of the present gulf are considerably younger than the entrance of seawater in the area. Arc volcanism in central and southern Baja California ended about the time of the first marine incursion, ca. 12.5 Ma (Sawlan and Smith, 1984), but reorganization of

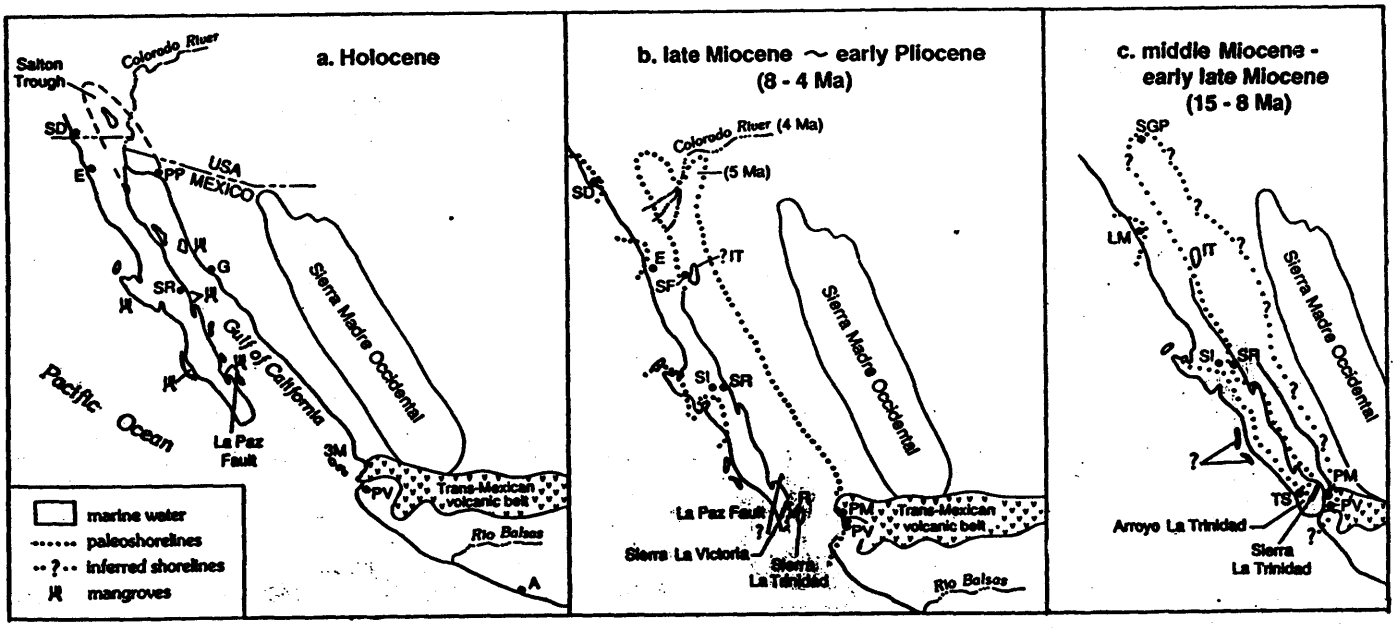

Figure 1 Paleogeography of the Gulf of California according to marine molluscan distributions, 15 MA to the present. A, Acapulco; E, Ensenada; G, Guaymas; 3M, Tres Marias Islands; IT, Tiburon Island; LM, La Mision; PM, Punta Mita; PP, Puerto Peñasco; PV, Puerto Vallarta; R, Rancho el Refugio; SD, San Diego; SF, San Felipe; SGP, San Gorgonio Pass, CA; SI, San Ignacio; SR, Santa Rosalia; TS, Todos Santos.

spreading events at 6.5-3.5 (Mammerickx and Klitgord, 1982) and much of the faulting in the Salton Trough were younger. Data constraining the timing of these events include radiometric ages of volcanic rocks associated with marine sediments as well as evolutionary sequences of index fossils (see for example the *Spondylus* lineage on Plate 4). Combined faunal and radiometric data offer possibilities of greater resolution in dating events in the evolution of the Gulf and correlating distant reference sections, especially those of different biofacies. They show that the history of the Gulf cannot be told from records near its mouth alone, as critical as that area is, and that previously published reconstruction models need to be reconsidered in light of a longer time frame.

Previous work

Previous work on the Gulf of California including the Salton Trough is summarized in a number of papers, including McCloy and others (1988), Kidwell (1988), Powell (1986, 1988), Winker (1987), Smith (1988 and 1989, in press), and papers in review volumes edited by Frizzell (1984), Rigsby (1984), and Dauphin and Simoneit (1989, in press). Fossil mollusks from the Gulf are illustrated in Jordan and Hertlein (1926), Hanna and Hertlein (1927), Hertlein (1966), Durham (1950), Hertlein and Emerson (1959), and Smith (1989).

Middle and Late Pliocene marine mollusks from the southern Gulf at the time of the "mid Pliocene spreading event" (ca. 4.5 Ma).

Ages are difficult to verify for marine mollusks living in shallow embayments in the southern Gulf. Few datable volcanic rocks are associated with late Neogene fossiliferous sediments, except in the area north of Loreto (McLean, 1987, 1988). Elsewhere in the southern gulf ages are construed by interpolation from microfossil zonation in the Tres Marias Islands (McCloy and others, 1988) or correlation using megafossils whose ranges are in turn constrained by radiometric data in the central and northern gulf (Smith, 1989). A suite of shallow water mollusks representing ca. 3.5- 2.5 Ma is here referred to informally as the "mid-Pliocene spreading event assemblage;" it consists of species common in the Gulf at the time the Baja California peninsula began to separate from mainland Mexico. Index species, several of which are figured on Plate 1, include the pelecypods *Argopecten abietis, Argopecten revellei, "Aequipecten" dallasi, Leopecten bakeri, Nodipecten arthriticus,* and large *Clypeaster* echinoids. Endemic or Pacific-Panamic in faunal affinity, the Argopectens are gregarious scallops found in large concentrations similar to *Argopecten circularis* beds at 15 - 20 m today. All except *Nodipecten arthriticus* became extinct before the Pleistocene.

The assemblage is found in unnamed sediments on the Tres Marias Islands (Madre and Cleofas), on many of the southern gulf islands (Emerson and Hertlein, 1964), the Loreto embayment, and the Infierno Formation of Wilson (1948, p. 1783) near Santa Rosalía. Since extensive deposits of marine sediments are known from the northern Gulf but not yet sampled for mollusks, northern ranges for the "mid-Pliocene spreading event assemblage" are not yet verified.

Middle to late Pliocene molluscan species at Maria Madre Island represent a bank top faunule that occupied a seamount well removed from a source of continental sediments (McCloy and others, 1988). They are found in 150 to 200 m thick massive beds that overlie the Arroyo Hondo diatomite that, according to diatom and radiolarian correlations, was deposited in the Tres Marias Basin ca. 8.2 Ma (McCloy and others, 1988). The basin subsided from early late Miocene through middle Pliocene; uplift of the submarine bank offered a suitable habitat for shallow neritic mollusks until the late Pleistocene when the island rose above sealevel.

Elsewhere in the southern Gulf the same species are found on the east side of Maria Cleofas Island (Hertlein and Emerson, 1959, American Museum of Natural History collections) and on southwestern Cerralvo Island (Hanna and Hertlein, 1927; Hertlein, 1957; Emerson and Hertlein, 1964; Hertlein, 1966; Durham, 1965 field notes, and Smith field reconnaissance for this paper). The Cerralvo locality, mislocated in the literature, is between the "Farallones blancos" of Hertlein (1966, fig. 1) and an arroyo on the north side of the Ruffo's Ranch site, 10 km south of El Mostrador. Rocks include white algal limestone, coquina, sandstone, and cobble to boulder conglomerate exposed in seacliffs for about 1.5 km along the beach. *Argopecten abietis* is especially abundant in the lower outcrops. Ash-flow tuff on the north end of this mainly pre-Tertiary basement island are not closely associated with the sediments (Smith and Sawlan, 1983, oral communication), and what seem to be beds of white volcanic tuff are ledge-forming sandstone containing concentrations of *Leopecten bakeri.*

Late Pliocene Records in the Loreto area

Larger, more diverse assemblages of Gulf mollusks are found on Carmen Island and north of Loreto in rocks referred to the Carmen-Marquer Formation, undifferentiated (Durham, 1950; McLean, 1988). Additional localities include southern Coronado Island in the low terrace 20 feet above low tide, southwestern Monserrate Island, and most

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Plate 1 "Mid-Pliocene spreading event assemblage," southern and central Gulf of California.

Figure 1 *Turritella marcosensis* Durham, 1950. Latex mold, hypotype USNM 418217, ht 5.2 cm. USGS loc. M9048, Carmen-Marquer Formation, undifferentiated, north of Loreto, B.C.S.; also occurs at Cerralvo and San Marcos Islands.

Figure 2 *Turritella* sp. Hypotype USNM 418215, ht 4.4 cm. USGS loc. M9057 = Smith loc. 86JS14e, Carmen-Marquer Formation, undifferentiated, north of Loreto, B.C.S. Also at Cerralvo Island.

Figures 3, 4 *Leopecten bakeri* (Hanna and Hertlein, 1927). LV, RV, ht. 11.9 cm, lth 13.3 cm, Smith field loc. 83JS7, "*Leopecten* ledge" [= CAS loc. 38543].

Figure 5 *Nodipecten arthriticus* (Reeve, 1853). LV, voucher specimen CAS 60985, ht 7cm, lth 7.6 cm. CAS loc. 38543, unnamed sediments, Cerralvo Island.

Figure 6 *Argopecten abietis* (Jordan and Hertlein, 1926). LV, ht. 10 cm, lth 10.8 cm. USGS loc. M9045 = Smith loc. 84JS22, Carmen-Marquer Formation, undifferentiated, Arroyo de Arce, north of Loreto, B.C.S. Also at Cerralvo and Maria Madre Islands.

Plate explanations: RV, right valve; LV, left valve; locality data on file at Cenozoic register, Menlo Park, California or from author.