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Paleocurrent evidence for lateral displacement of the Pliocene Colorado River delta by the San Andreas fault system, southeastern California

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ABSTRACT

More than 600 paleocurrent measurements from fluvial paleochannels of the early Colorado River delta plain, preserved in the Palm Spring Formation in the Fish Creek–Vallecito (FCV) section of southern California, indicate that the FCV section was on the Gulf of California (southeastern) flank of the delta plain as recently as 2.8 Ma. These measurements imply ~130 km of tectonic translation to the northwest since 2.8 Ma, which can be accounted for by the displacement histories of Baja California and component faults of the San Andreas system. Stratigraphic data from the FCV section and other Neogene localities, when plotted on a palinspastic base, indicate (1) marine transgression of a narrow Gulf of California rift basin and Bouse embayment (site of modern lower Colorado River) by 5.5 Ma, and (2) uplift of the Bouse embayment, initiation of the lower Colorado River, and southward progradation of the delta to essentially its present position by 4 Ma.

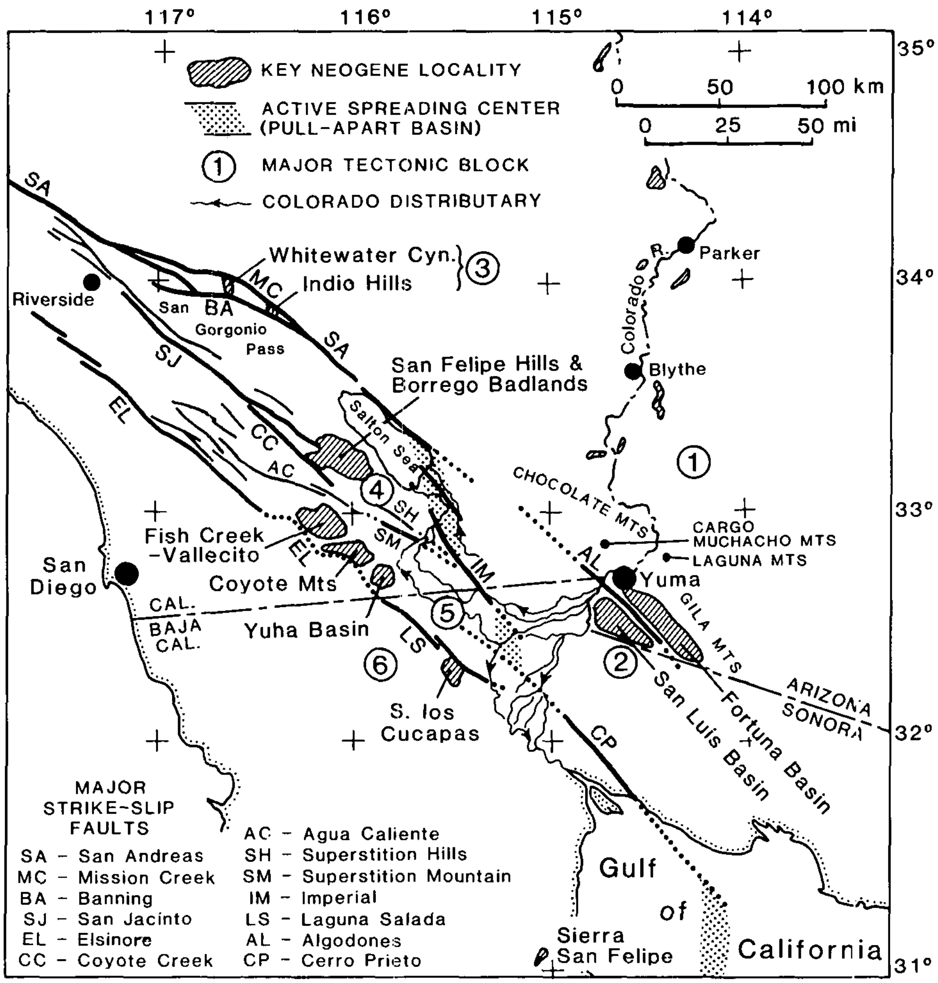

Figure 1. Location of Fish Creek–Vallecito study area in relation to San Andreas fault system, modern Colorado River and delta, northern Gulf of California, and other Neogene localities.

INTRODUCTION

Paleocurrents from the pre-Holocene Colorado River delta are potentially useful in constraining paleogeographic reconstructions of the northern Gulf of California, which has accommodated ~300 km of late Cenozoic dextral offset of Baja California relative to the North American plate along the San Andreas fault system (Moore and Curray, 1982).

The modern Colorado River enters the Salton trough through a gap between the Chocolate and Laguna mountains on the North American plate (Fig. 1), and its radial-bipolar delta plain fans out from that point. The presence of Colorado River alluvium—postdating the lower Pliocene Bouse Formation—along the lower Colorado River valley and in the Yuma Desert southwest of the gap (Olmsted et al., 1973) suggests that the river has occupied this gap since the early Pliocene. The stratigraphic record of a tectonic block translated past the Chocolate-Laguna gap by transcurrent faulting would thus be expected to exhibit upsection clockwise rotation of fluvial paleocurrents, recording movement of the subsiding block from the southeast to the northwest flank

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of the Colorado River delta plain. We examined Pliocene deltaic sediments of the Fish Creek–Vallecito (FCV) section (Fig. 1) for evidence of paleocurrent directions incompatible with the present location of the section on the western side of the Salton trough.

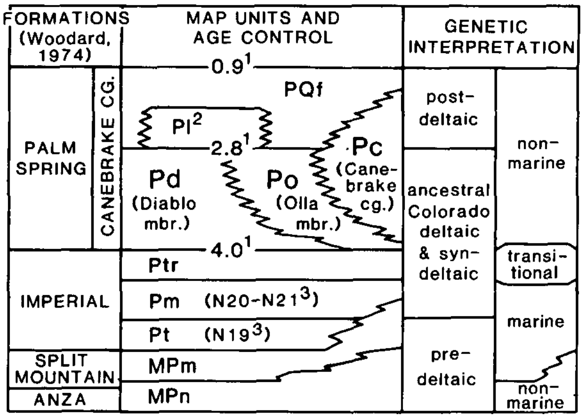
DELTAIC SEQUENCE AND PALEOCURRENTS

In the FCV section, located on the western edge of the Salton trough and modern Imperial Valley (Fig. 1), Pliocene delta plain environments are inferred for a thick (~2.5 km) interval of nonmarine sandstone, siltstone, and claystone mapped as the Diablo and Olla members of the Palm Spring Formation (Fig. 2).

The Diablo contains lenticular bodies of massive, upward-fining sandstone (average ~5-m-thick cycles) that has parallel, convolute, and low-angle cross-laminations and, less commonly, trough cross-stratification. Claystone intraclasts mark the base of these paleochannel sand deposits. Intervening red claystones, interbedded with ripple-laminated siltstone that has mudcracks and rare paleocaliche horizons, are interpreted as overbank deposits of the meandering river system.

The Diablo member caps a 3.5-km-thick progradational sequence of Colorado River–derived (1) turbiditic sandstones; (2) prodeltaic claystones and rhythmically bedded siltstones; (3) upward-coarsening delta-front cycles of claystone, siltstone rhythmites, and oyster-rich sandstone; and (4) bioturbated to wavy-bedded tidal-flat deposits (Fig. 2). These paleoenvironmental interpretations agree with previous paleoecologic studies based on ostracodes (Quinn and Cronin, 1984). Sandstones derived from the Colorado River, previously recognized in the study area by Merriam and Bandy (1965) on petrographic criteria, can be readily identified in the field. They are typically pale orange, well sorted, uniformly fine to very fine grained, and low in mica, whereas locally derived sandstones are gray to olive, less well sorted, more angular, and biotite-rich in the finer grain sizes.

Diablo-like sequences of Colorado River–derived sediment alternate and interfinger laterally with gray to olive sandstones in the Olla member, which in turn grades laterally into the locally derived Canebrake fanglomerate found in contact with plutonic basement (Figs. 2 and 3). The Olla member is interpreted as distal deposits of alluvial fans and braided streams that alternated with deposits of laterally migrating channels of the ancestral Colorado River delta plain. A sharp and laterally persistent contact at the top of the Diablo and Olla members (Figs. 2 and 3) marks the stratigraphically



¹magnetostratigraphic ages in Ma (Johnson et al., 1983; P. Remeika, 1985, written comm.)
²2.3±0.4 Ma, fission-track age on zircon from air-fall tuff (Johnson et al., 1983)
³planktonic foraminiferal zones (Stump, 1972)

Figure 2. Stratigraphic summary of Fish Creek–Vallecito section. Map-unit symbols in center column refer to Figure 3. Informal nomenclature for members modified from Woodard (1963).

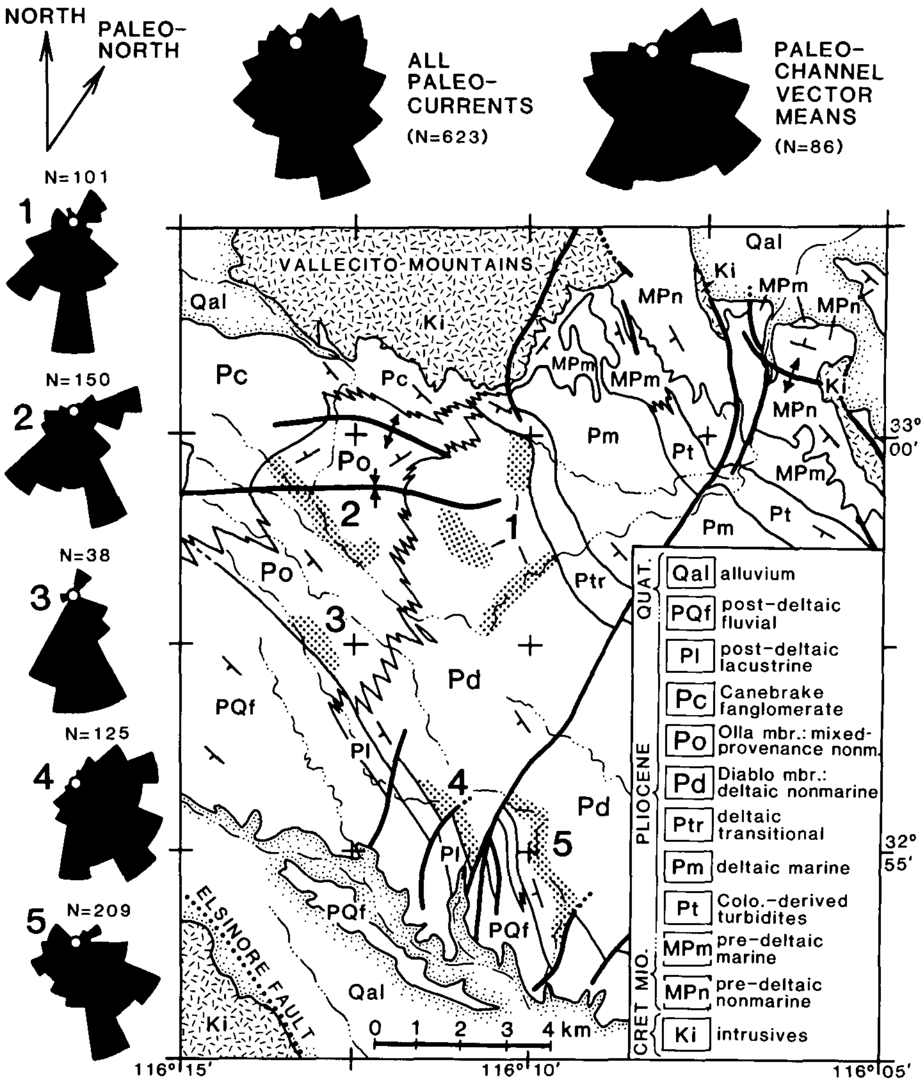


Figure 3. Generalized geologic map of Fish Creek–Vallecito study area. Paleocurrent roses are based on trough cross-stratification from paleochannels in Diablo and Olla members (coarse stippling indicates where data were collected) and are oriented with respect to map and modern north. Paleonorth arrow is based on paleomagnetic declinations from Johnson et al. (1983).

highest occurrence of Colorado River–derived sandstones. This contact is estimated at 2.8 Ma by linear interpolation between paleomagnetic reversals dated at 2.9 and 2.5 Ma (Johnson et al., 1983; P. Remeika, 1985, written commun.).

Foresets in trough cross-stratified paleochannel sandstones of the Diablo and Olla members yielded predominantly southerly paleocurrent directions (Fig. 3) with considerable scatter, as expected for a meandering fluvial system. Paleomagnetic declinations indicate that the FCV section has rotated ~35° clockwise since 0.9 Ma (Johnson et al., 1983). A counterclockwise back-rotation of the paleocurrent measurements to correct for this tectonic rotation results in a dominant southeasterly paleocurrent direction. These results suggest that the FCV section was on the southeastern, or gulfward, flank of the Colorado delta plain from 4 Ma until at least 2.8 Ma, at which time the supply of Colorado River sediment to the FCV section was shut off.

TECTONIC DISPLACEMENTS AND PALINSPASTIC RECONSTRUCTION

Are these paleocurrent directions compatible with tectonic displacements inferred from other lines of evidence? Using the simplifying assumptions of constant slip rates and straight, parallel tectonic trajectories (Fig. 4A), we plotted a preliminary palinspastic model. This model is based on the hypothesis of Moore and Curray (1982) that Baja California has moved northwest at 56 mm/yr since 5.5 Ma, for a total displacement of ~310 km. This total displacement can be accounted for in the Salton trough–northern gulf region by individual displacements on several major strike-slip faults (Fig. 1): (1) ~20 km on the Agua Blanca fault (Allen et al., 1960); (2) ~40 km on the Elsinore fault (Sage, 1973; Crowell and Ramirez, 1979); (3) ~25 km on the San Jacinto fault (Sharp, 1967); and (4) 180 km (Dillon, 1975) to 215 km (Peterson, 1975) on the Mission Creek branch of the San Andreas fault (the latter figure is arbitrarily assumed in our model). Most of the residual displacement (~10 km) is presumably accommodated by the Banning fault. The Algodones fault has been postulated as a former extension of the San Andreas fault (Crowell and Ramirez, 1979), but strike-slip offset has not been demonstrated.

Slip rates on all faults (except the Algodones) are assumed to be constant from 5.5 Ma to the present. This assumption is probably incorrect; for example, the San Jacinto fault may have originated as recently as the Pleistocene (Bartholomew, 1970). However, our palinspastic base provides a geometrically simple reference model to which additional complications

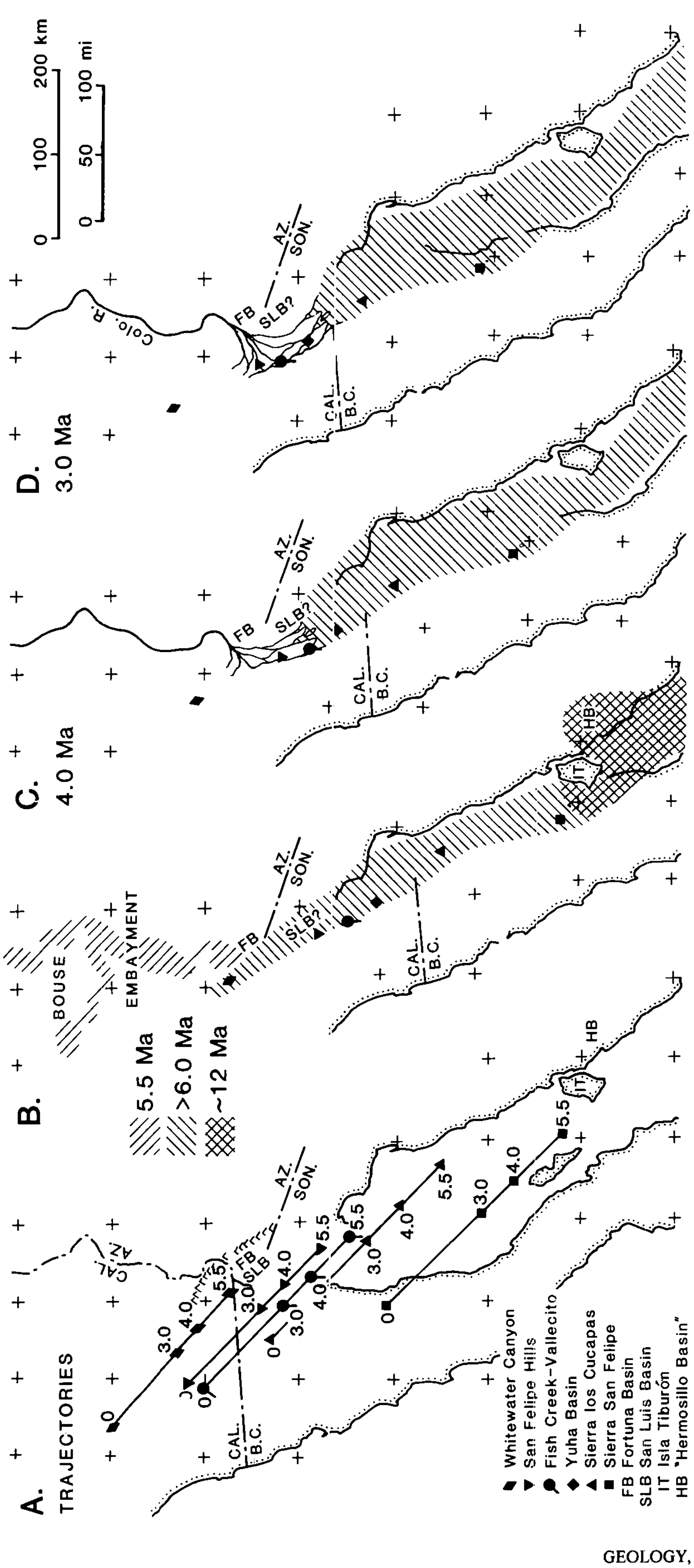


Figure 4. Paleogeographic reconstructions of Neogene northern Gulf of California and Colorado delta. A: Tectonic trajectories used to construct palinspastic base maps. B: Extent of marine basin prior to Colorado delta. Timing of transgression is based on radiometric ages from Isla Tiburón (Smith et al., 1985), Whitewater Canyon (Matti et al., 1985), and Bouse embayment (Shafiqullah et al., 1980). C and D: Introduction of Colorado River–derived sediment into Salton trough implies end of marine Bouse embayment and initiation of through-flowing drainage. Fish Creek–Vallecito section is dominated by southeast-directed river channels along southwest margin of trough.

can be added and paleogeographic implications examined.

This model places the FCV section ~130 km southeast of its present position at 2.8 Ma and in a position southwest of the Chocolate-Laguna mountain gap, whereas the paleocurrents indicate a dominant southeasterly paleochannel orientation (Fig. 3). This discrepancy may be due to (1) an alternative entry point for the Pliocene Colorado River into the Salton trough (however, we are not aware of any Colorado River–derived fluvial sediment on the northeast margin of the trough outside of the Yuma area; Olmsted et al., 1973); (2) overestimation of the total displacement on the Elsinore fault and the Agua Blanca fault since 2.8 Ma; or (3) proximity of the FCV section to the southwest margin of the trough during the Pliocene, which resulted in deflection of paleochannels to the south and southeast. Lateral gradation of Diablo lithofacies with locally derived Olla and Canebrake facies (Fig. 3) indicates that the FCV section was probably near the western margin of the Pliocene Salton trough. Furthermore, that the same lateral facies tract occurs north of the San Felipe Hills and in the western Coyote Mountains indicates a northwest-southeast orientation for the margin of the Pliocene basin (after correction for tectonic rotation). Paleocurrent directions for Colorado distributary paleochannels in the FCV section are thus approximately parallel to the contemporaneous basin margin.

PALEOGEOGRAPHY OF THE EARLY GULF AND COLORADO RIVER DELTA

Using the palinspastic base developed in the previous section, we have reconstructed the pre-deltaic gulf (Fig. 4B) as a long, narrow (~50 km wide), fairly straight basin, suggestive of a rift basin. Transgression apparently proceeded in two steps. The first phase occurred in the early or middle Miocene (Gómez, 1971) and reached Isla Tiburón by 12 Ma (Smith et al., 1985). The second phase of transgression reached Sierra San Felipe at least by 5.5–6.0 Ma (Boehm, 1984) and Whitewater Canyon before 6.0 Ma (Matti et al., 1985) and spilled over into the Bouse embayment (Olmsted et al., 1973; Metzger et al., 1973) by 5.5 Ma (Shafiqullah et al., 1980).

On the basis of magnetostratigraphy of Johnson et al. (1983), the first Colorado River–derived sediment arrived in the FCV no later than 4.3 Ma. Introduction of Colorado River–derived sediment to the Salton trough is attributed to uplift and emergence of the Bouse embayment and consequent initiation and entrenchment of the lower Colorado River (Olmsted et al., 1973; Metzger et al., 1973), which occurred between 5.5 and 3.8 Ma (Shafiqullah et al., 1980).

The marine-nonmarine transition in the FCV section is dated at ~4.0 Ma (Johnson et al., 1983) (Fig. 2). This transition took place when the FCV section was at about the same geographic location relative to the North American plate as the marine-nonmarine transition in the present delta (Fig. 4C). The deltaic shoreline had therefore apparently prograded southward to approximately its present position by 4.0 Ma. Subsequently, it appears that the delta has remained in a predominantly aggradational mode while the Salton trough opened and widened beneath it.

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