A Tale of Two Eocene Sands

by Henry Walrond

"The hypothesis of cumulative right-lateral displacement on the San Andreas Fault of hundreds of miles since Jurassic has received very wide acceptance among earth scientists, even to the point of incorporation into a number of leading textbooks, as more-or-less qualified fact for the instruction of young geologists"
—Gordon Oakeshott, 1965

Introduction

This paper is the result of a study of the relationship and possible source connection between two of the largest Eocene sand bodies in the southern San Joaquin basin — the Lower Eocene Cantua/Gatchell/Yokut series of the Coalinga area and the Upper Eocene Point of Rocks that extends south along the west side of the basin from Pyramid Hills to Elk Hills. It seemed to be more than coincidence that Point of Rocks deposition started almost immediately after the deposition of the Lower Eocene sands stopped in the Coalinga area. This curious sequence or apparent transfer of sand deposition from one area to the other (north to south, pre-Domengine to post-Domengine), without overlap of deposition in time, suggested a genetic connection. As this study developed, it became apparent that, in addition to the possible "Two Sands" relationship, other associated sedimentary events in the basin remain controversial or as of yet unexplained:

1. In addition to the intriguing sequence of the "Two Sands", there is the question regarding their source terrains.

2. What instigated, and what was the source and depositional environment of, the Middle Eocene Domengine transgression?

3. What best explains the unusual shallow/bathyl-water relationship between the Domengine and the immediately overlying Kreyenhagen?

4. Why is there Eocene salt deposition at Elk Hills?

This report ties the Lower Eocene Cantua/Gatchell/Yokut of the Coalinga area and the Upper Eocene Point of Rocks located along the west side of the basin to a common westerly marine basin (La Honda) and source terrain (Gabilan granites), and at the same time it explains the transfer of sand deposition from north to south (Lower to Upper Eocene). A scenario is also offered for the dramatic and widespread Domengine transgression that rapidly covered most of the southern San Joaquin basin to usher in the Upper Eocene, and how this relates to the juxtaposition of the shallow-water basal transgressive Domengine sand and the overlying bathyl Kreyenhagen shale. Finally, an explanation is proposed for the pre-Domengine salt section penetrated at Elk Hills in Sec.25, T.30S, R.23E (Figure1).

Antecedents

Much has been written on the Lower Eocene sands in the Coalinga/Vallecitos area, and whether their source was east (Sierran) (Graham and Berry, 1980; Ryall, 1974) or west (Salinian) of the San Andreas Fault System (hereafter SAFS) (Dibblee and Nilsen, 1974). Although views differ regarding the locality, a Salinian source for the Point of Rocks is generally accepted. In both instances, most investigators adhere to the concept of large, right lateral movement on the SAFS for their match-ups. Both the Coalinga Lower Eocene (for a western source proposal) and the Upper Eocene Point of Rocks sands require offsets of as much as 200 mi. In this paper I conclude that, despite considerable fault and other tectonic activity, no significant lateral offset occurred on the San Andreas Fault since early Eocene time.

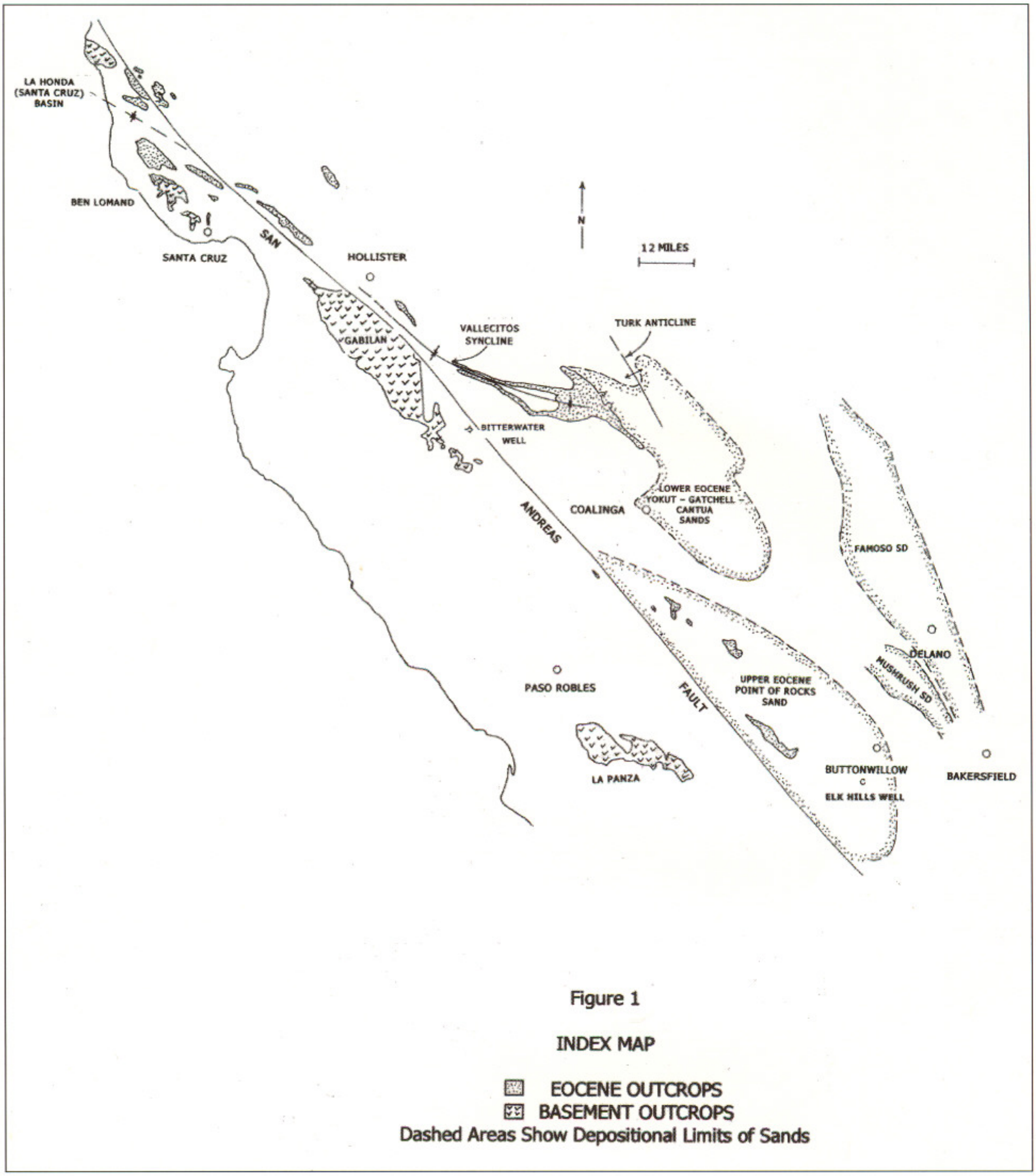

Figure 1. Map showing Lower and Upper Eocene sand distribution, outcrops, and subsurface limits of deposition. In the La Honda basin a full and uninterrupted sequence of Eocene is present.

The Sands (Figure 2; all paleontological designations are from Laiming, 1940)

SAN JOAQUIN BASIN

COALINGA AREA

Lower Eocene
Cantua – "C" Zone
Gatchell & lower McAdams – "B-2 to B-4" Zone
Yokut, upper McAdams & Loescher – "B-1" Zone

The Gatchell and lower McAdams are probably a more distal or basin facies of the "upper" Cantua of the Vallecitos channel.

Middle Eocene
Domengine, Avenal & Mabury-Basal Kreyenhagen – "A-2/B-1" Zone

The Domengine and the time-equivalent Mabury and Avenal sands are the basal transgressive members of the Kreyenhagen formation. Although the Domengine is usually referred to as a sand, it is in most areas a thin, reworked unit that cannibalized underlying, transgressed sediments (i.e., where overlying the Yokut sand, it is a sand; farther to the east where it overlies the Paleocene siltstone, it is a grit).

PYRAMID HILLS-ELK HILLS AREA

Upper Eocene
Point of Rocks sand – A deepwater turbidite fan
A facies of the Kreyenhagen shale formation – "A-1 and A-2" Zone.

LA HONDA (Santa Cruz) BASIN

Lower to Lower Upper Eocene
Butano sand – A deepwater turbidite fan – "C-1 to A-2" Zones.

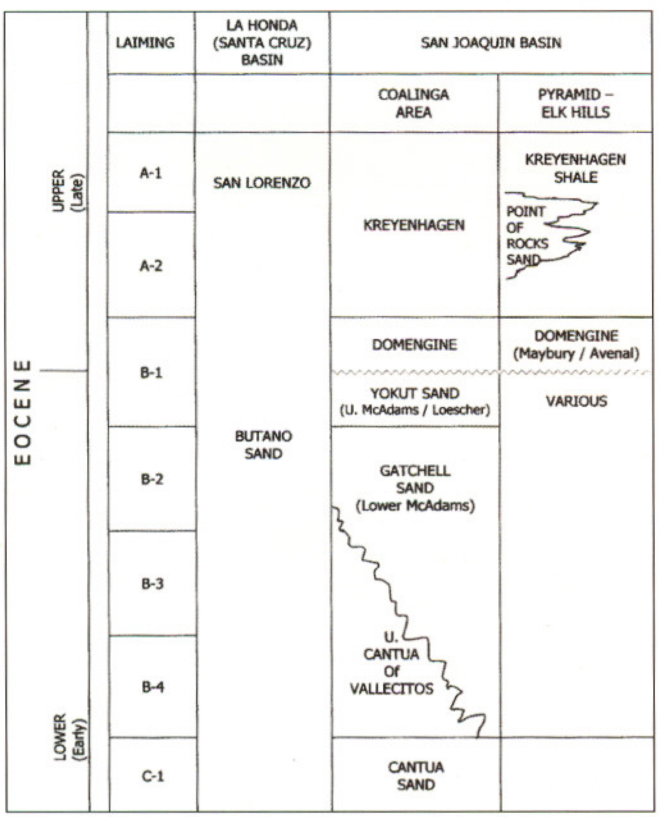

Figure 2. Stratigraphic column showing time scale and rock units discussed in this report. (Paleontological designations from Laiming, 1940)

Basic General Assumptions

1. During Eocene time, the southern Sierra Nevada area was structurally positive, but not with sufficient relief to contribute significant sand to the subject areas. Exceptions, but not necessarily related depositionally, are the pre-Domengine Mushrush and the Kreyenhagen-equivalent Famoso sands, both of whose sources were in the southern Sierra Nevada area. These sands appear to be restricted to the southeast flank of the San Joaquin basin (the Famoso more widespread than the Mushrush), and they are only time related to the sands under discussion. This is also the case of the Upper Eocene sands of the Tejon area.

[An aside: Fossiliferous beds in the thick, mostly nonmarine Goler Formation, located east of the southern Sierra Nevada in the El Paso Mountains north of the Garlock fault, reportedly represent an early Eocene marine transgression. If, as has been proposed, both the Mushrush (Reid, 1988) and the Goler (Cox, 1987) sands are pre-Domengine, they may be depositionally related, and the Tehachapi Valley and Sierra Tejon-crest wind gap (aligned with and located just east of the Tehachapi Valley) could be the successive uplifted, erosional remnants of a trans-Sierra seaway that connected those two deposits during early Eocene time.]

2. The SAFS, a pre-Tertiary, tectonically active and mobile trend, has played a duel role. It has strongly influenced erosional patterns (as well illustrated by current topography), deposition, and the alignment of basins. On the other hand, because of constant structural activity (especially pronounced on the easterly, plastic Franciscan-Cretaceous side of the fault), outcrop evidence of much of the Tertiary and especially the Eocene depositional history has been removed through long stretches of the fault. You might say that the San Andreas "giveth" and the San Andreas "taketh" away.

3. The main source for all of the subject Eocene sands, including the Butano of the La Honda basin, was the Gabilan granitic basement (Figure 3). It is partially exposed today, but in the past it extended from as far north as Ben Lomand on the southwest flank of the La Honda basin to as far south as the La Panza basement outcrops southeast of Paso Robles.

4. The Vallecitos syncline, a relict of a northwesterly trending down warp was, via the La Honda basin, the Lower Eocene connection between the southern San Joaquin basin and the Pacific Ocean.

The Proposal

At the beginning of Eocene time, granitic sands from the eroding Gabilan were carried into a northerly flowing SAFS-dominated drainage system (called the San Andreas river in this paper) and discharged sand into the La Honda-Vallecitos seaway. This constricted seaway had, because of a combination of subsidence, consequent basin expansion and evaporation, a net southeasterly flow that transported the first Eocene sands into the San Joaquin basin. Although the initial incursion was aerially limited, over 3000 ft of what is customarily called Cantua sand (the upper part is probably Gatchell equivalent; Ryall, 1974) accumulated in the restricted low near the mouth of the Vallecitos trough before minor amounts of sand spilled farther southeast into the San Joaquin basin (Figure 3).

Following the initial somewhat restricted accumulation of the "lower" Cantua sequence of the Vallecitos, coarse granitic sediments, now with the inclusion of some reworked Cretaceous (Regan, 1943), continued to pour into the channel throughout "upper" Cantua (Gatchell) time; and from there into the basin proper, forming the more widespread, north-south-trending Gatchell bar or spit. Like the Cantua, the bar reached its maximum thickness of 900 ft in or near the mouth of the channel (Figure 4).

Next, with contributions now from both the Cretaceous and Franciscan, the granitic sands continued to feed the basin via a shallower Vallecitos channel throughout Yokut time. This formed a more sheetlike deltaic deposit with an isopach pattern in the north of several northwest-southeast-trending barlike buildups (Figure 5). Like both the Cantua and Gatchell sands, the Yokut's thickest development of 600 ft occurs at the mouth of the Vallecitos Channel. It is worth noting that all of the sands tended to trail off to the south, suggesting a basinal low in that direction.

Then, representing a momentous occurrence in California's geologic history, the easterly flow carrying the coarse Gabilan-sourced clastics suddenly ceased, marking the end of Lower Eocene sand deposition in this part of the basin. Uplift along the SAFS trend, an event telegraphed by the introduction of reworked Cretaceous and Franciscan clasts along with the sequential shallowing of the channel deposits throughout lower Eocene time, effectively severed the La Honda-Vallecitos connection. Subsidence in the southern San Joaquin basin probably continued during this time.

Little if any of sand entered the Coalinga area from either west or east after Yokut time. This is a key to the assumption (yet to be discussed) that the Sierra Nevada was not a likely source for most of the lower Eocene sands. Events along, or related to, the much more active, plastic and mobile San Andreas trend, rather than the more stable Sierran massif, most likely accounted for the temporary interruption and eventual diversion of marine flow and sedimentation.

How long the San Joaquin basin was isolated from a marine source is conjectural; but it was long enough for evaporation to deplete and concentrate the remaining water in a low area to the south. The concentration of

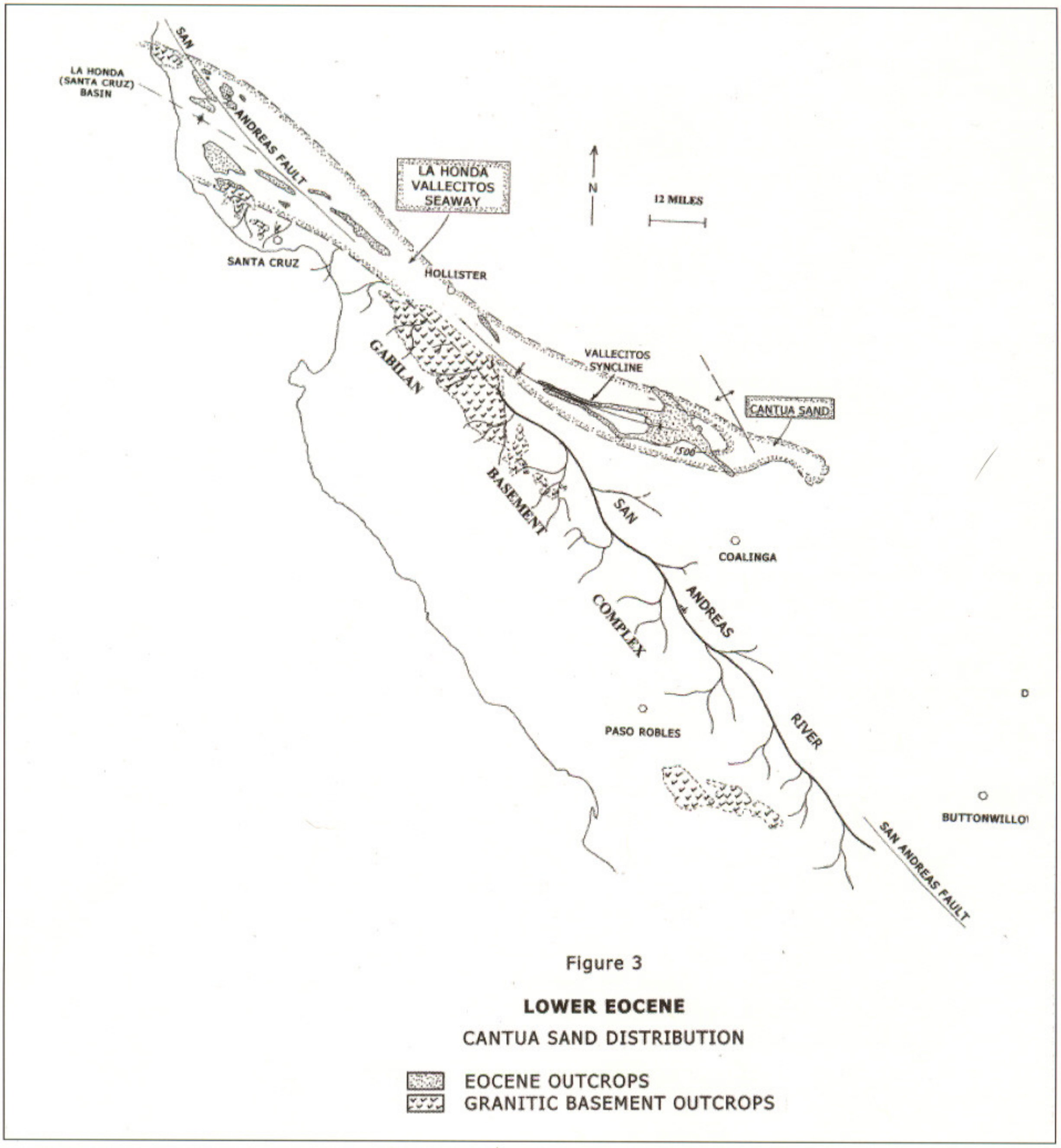

Figure 3. Map showing the Gabilan granitic sand source, the proposed southerly flowing Early Eocene La Honda-Vallecitos seaway, and the Cantua sand depositional limits in the San Joaquin basin.

highly saline water in the southern end of the basin would explain the precipitation of as much as 800 ft of pre-Domengine salt in the Elk Hills area (Fishburn, 1990). Following the accumulation of hundreds of feet of salt, the formerly inland sea became essentially a dry valley.

[An aside: The concept of a dry subsea basin during mid-Eocene in the southern San Joaquin is likely incomprehensible to most California geologists. However, comparable feelings probably prevailed before it was confirmed that the Mediterranean had been a dry subsea basin five million years prior to the massive Atlantic Ocean breakthrough at Gibraltar. And, of course, California's own Salton Sea basin was once dry, and 297 ft below sea level.]

The next event, in Middle Eocene or early in Upper Eocene time, was a marine breakthrough into the San Joaquin Valley from the Pacific, extending southerly through the La Honda basin. This time the breakthrough was guided by the previously eroded San Andreas river valley (channel piracy). This initial flood, the Domengine

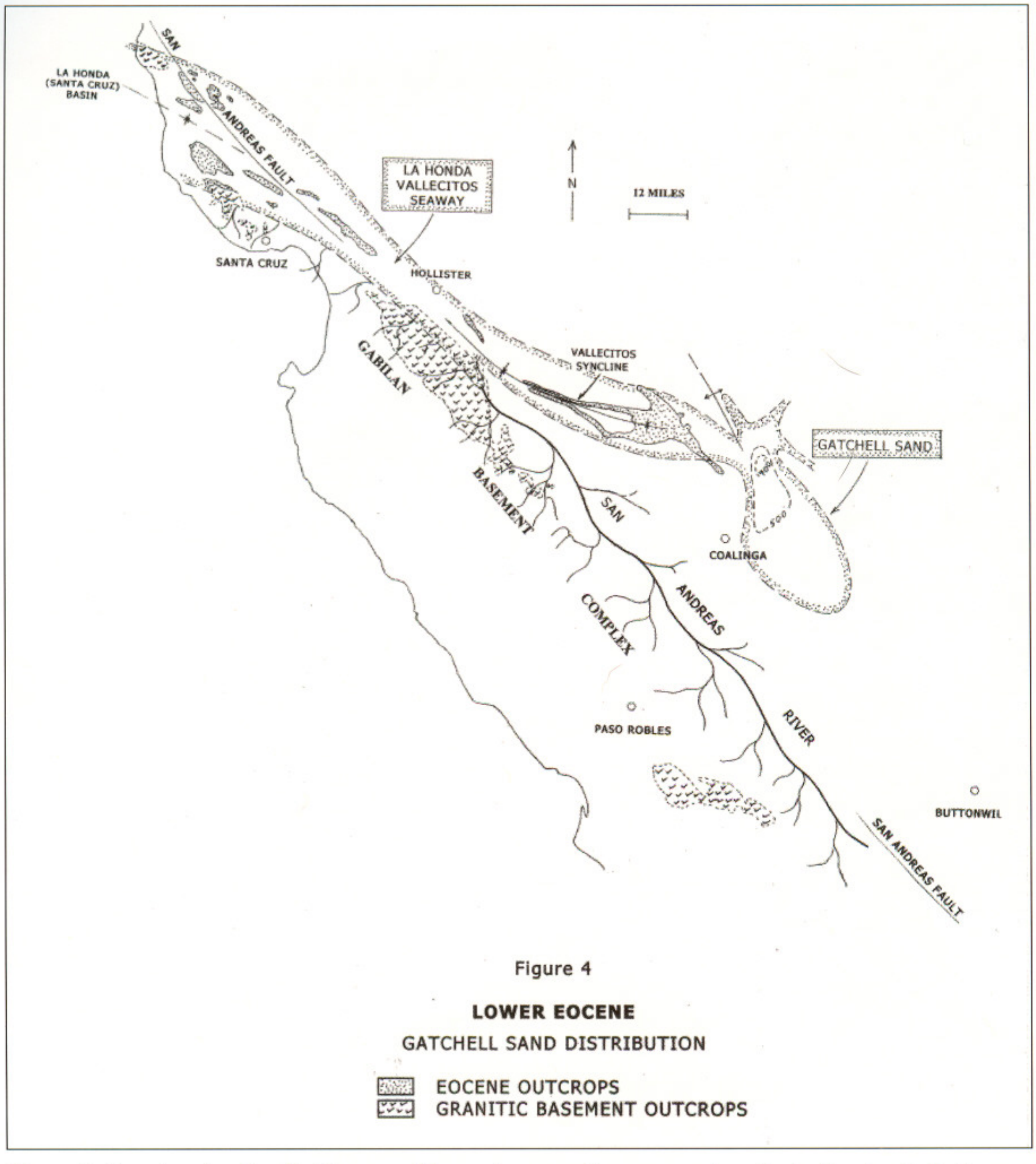

Figure 4. Map showing the Gabilan granitic sand source, the proposed southerly flowing Early Eocene La Honda-Vallecitos seaway, and the subsurface depositional limits of Gatchell-Lower McAdams sands in the San Joaquin basin.

transgression, advanced rapidly over the dry and deep San Joaquin basin. With a then-unlimited supply of water, the valley quickly filled to sea level establishing the deepwater marine environment associated with Kreyenhagen shale deposition that covered most of the basin. Meanwhile, the time-equivalent Point of Rocks sands, derived from the greater Gabilan and fed through the mouth of the new SAFS seaway, accumulated on the shallow westerly shore of the basin and, as a consequence of overloading and wave action, were redeposited as a turbidite fan into the deep westerly portion of the basin (Figure 6).

As previously mentioned, the Famoso sand was being deposited concurrently with the Point of Rocks on the southeast flank of the basin. However, there is little evidence, based on the thick blanket of Kreyenhagen shale covering the area farther north, to suggest any significant coeval contribution of Sierran sand to the basin deep other than that expected from shoreline erosion.

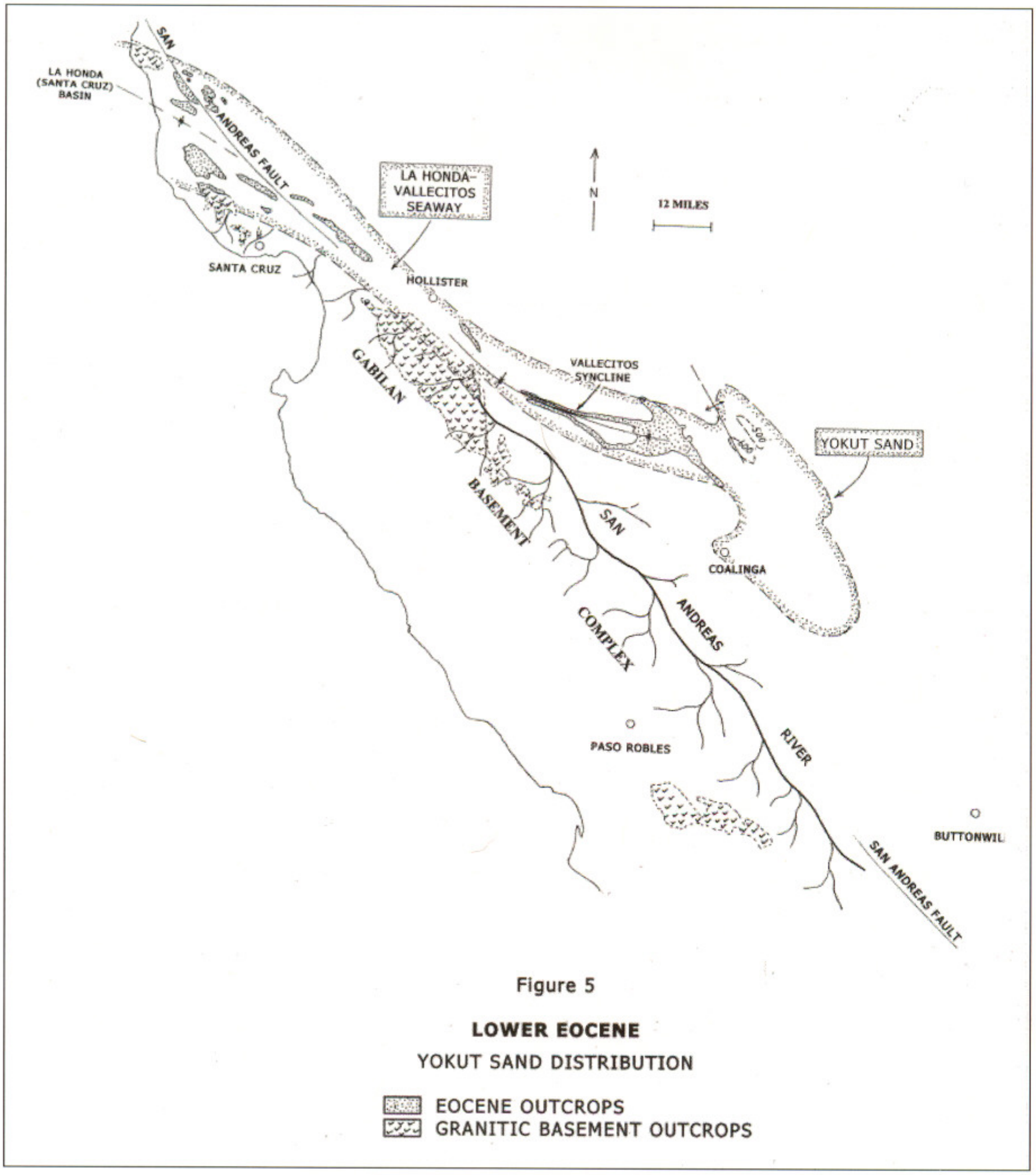

Figure 5. Map showing the Gabilan granitic sand source, the proposed southerly flowing Early Eocene La Honda-Vallecitos seaway, and the subsurface depositional limits of Yokut-Upper McAdams sands in the San Joaquin basin.

In the Vallecitos area, there was a renewed Eocene presence; only this time the marine advance was from the east or expanding inland sea, and the only new sand was the Domengine reworked from the Yokut during the transgression. Kreyenhagen shale was deposited during the remainder of the Late Eocene.

The seemingly paradoxical juxtaposition of shallow-water Domengine sands in direct depositional contact with the overlying bathyl Kreyenhagen shale is now easily explained as the result of a massive, pervading marine transgression over the dry and deep, subsea valley followed quickly by the resumption of deepwater deposition as the basin regained sea level.

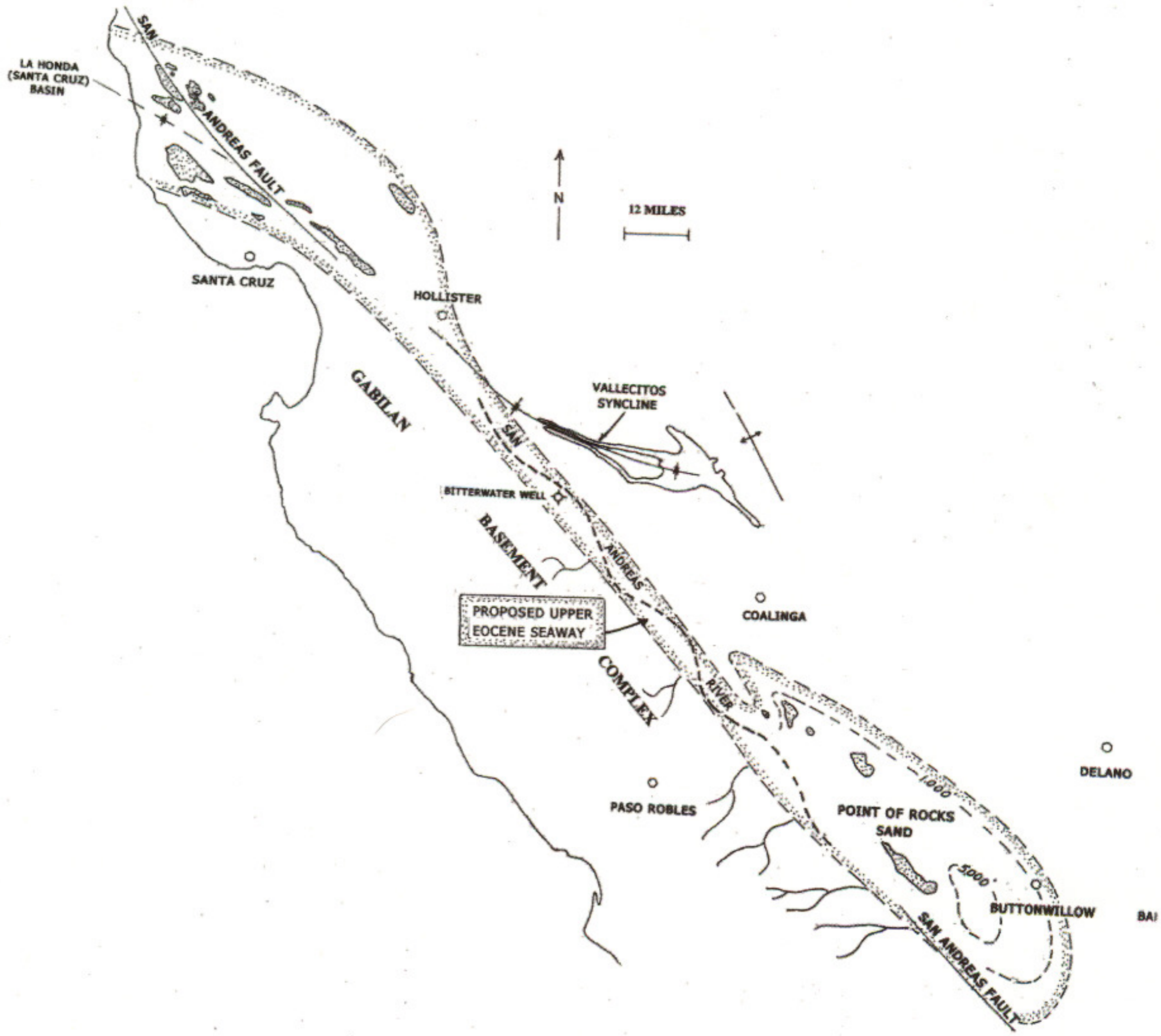

Figure 6

UPPER EOCENE

Point of Rocks Sand Distribution Showing Proposed Upper Eocene San Andreas Channel Connection with the Pacific via the La Honda Basin

EOCENE OUTCROPS
GRANITIC BASEMENT OUTCROPS

Figure 6. Map showing location of the deepwater Upper Eocene Point of Rocks turbidite fan and its proposed seaway connection bordering the Gabilan source area, where it extends south along the San Andreas fault trend from the La Honda basin.

Discussion

Vallecitos-Coalinga Area: Lower Eocene Sand Source

Current proposals for the origin of the Lower Eocene sands near Coalinga include a Sierran source to the east (Graham and Berry, 1980; Ryall, 1974) and a western or Salinian connection across the San Andreas Fault (Regan, 1943; Dibblee and Nilsen, 1974).

Westerly Connection

Consistent with prevailing opinions, most Salinian or western source proponents call on considerable right-lateral offset (up to 200 mi) on the SAFS. This requires a depositional connection between the Cantua/Gatchell and the German Rancho sands outcropping on the coast north of San Francisco, west of the SAFS. Although the German Rancho and Cantua sands are apparently the same age, their lithologies are mismatched. Despite this, a large right-lateral Lower Eocene displacement is proposed, in part to be in harmony with "previously determined offsets" of younger and older strata (Dibblee and Nilsen, 1974).

Easterly Connection

A Sierran source via a submarine canyon is another postulate for the lower Eocene Cantua/Gatchell sands of the Coalinga-Vallecitos area (the Yokut, for some reason, is left out). This is supported by a good compositional match between source and sand (Graham and Berry, 1980). The match does not clearly extend into the overlying shallower Gatchell, however, which consists of considerable reworked Cretaceous, nor the very shallow-water Yokut sands, which contain Franciscan-derived andalucite (Regan, 1943). In addition to the above compositional discrepancies, further examination of the individual sand bodies raises other concerns. First it must be pointed out that 3,000 ft or more of what is called "Cantua" in the Vallecitos syncline by most workers is not a uniform sand as to age or mode of deposition. Phill Ryall in his 1974 paper pointed out that the "lower" Cantua contained bathyl C-zone fauna associated with gravity-turbidite structures; while the "upper" Cantua sands were deposited in a different or shallow-water environment characterized by B-zone or Gatchell-age fauna (the channel source of the Gatchell bar).

"Lower" Cantua

For the deepwater "lower" Cantua channel/turbidite sands, the Sierran lithologic match is not questioned. However, embracing the complete eastern scenario for this deposit requires the acceptance of these sands being transported from a Sierran shelf across the basin by turbidity currents and then, not only being restricted to, but reaching a maximum thickness in and near the mouth of the Vallecitos. This proposal also has to adjust to the possibility that the Cantua sands extend as a channel 50 mi to the northwest where outcropping "C"-zone sands line up with the Vallecitos syncline just south of Hollister (Wilson, 1943).

"Upper" Cantua-Gatchell

In his aforementioned 1974 report, Ryall also presented a correlation section that shows the merging or connection (time equivalency) between the "upper" Cantua in the throat of the Vallecitos channel and the Gatchell of the East Coalinga Extension oil field. This correlation is a clear indication that the Gatchell is an offshore barlike feature equivalent to, and derived from, the "upper" and shallower Cantua channel sands of the Vallecitos to the west.

Gatchell

The Gatchell and the Cantua sands, although deposited in different environments, are usually grouped together in most reports. Although opinions often differ as to their relationship, there is a good reason for this because they are almost indisputably connected as revealed in the Ryall (1974) section. The controversy hinges on the nature of the connection. Recent evidence from exploratory drilling suggests a possible easterly source for some of the Gatchell sands. However, the Gatchell, unlike the Cantua, is not a turbidite. For this reason it is difficult to justify that gravity transportation led to the development of the main sand body or bar that is thickest and best developed on the western side of the basin just off the mouth of the Vallecitos channel. Also, a predominantly eastern source doesn't account for the presence of recycled Cretaceous, and finally doesn't enlighten the close (merging) relationship between the Cantua and Gatchell demonstrated by the Ryall (1974) section.

Yokut

Although the sequential and general paleographical relationship of the three lower Eocene formations suggests a close genealogical relationship, the Yokut, for some reason, is not included in the Sierran proposal. Because it is most likely connected to a western source, this necessitates a sudden source shift from east to west just before Yokut time — a complication that does nothing to solidify the overall Sierran proposal.

There is little direct or residual evidence of significant sand being derived from the east throughout all of the Eocene time, except for the aforementioned Mushrush and Famoso shelf-fringe sands. This is particularly true of the Kreyenhagen farther north in the latitude of Coalinga and Vallecitos, where it shows no sign of a major sand infusion from any direction except for minor amounts associated with shoreline erosion near the Sierra. The absence of Upper Eocene Kreyenhagen sand in the area is particularly significant because it is difficult to imagine the Sierra area debauching the great accumulation of sand through early Eocene time (that happens to be thickest in and at the mouth of the Vallecitos) and suddenly stopping in the Middle Eocene, coincident with the apparent marine cut-off that occurred prior to the Domengine transgression.

And finally, even if the Sierra Nevada provenance was the source of these older turbidite-channel sands, there is still a need for a connection between the ocean and the basin in Early Eocene time. So, if the "required" 200 mi offset along the San Andreas is accepted, it still requires connecting the San Joaquin basin (through the Vallecitos?) with the German Rancho submarine fan area, exposed on the coast to the north for the marine avenue. Also, to bring this proposal to a conclusion, it is necessary to either disregard the discrepancy of different compositions or assume there was no depositional interchange across the fault. Therefore, advocating an easterly sand source does not eliminate the need for a western cross-fault marine connection. It merely skirts the problem of a Coalinga-German Rancho lithologic mismatch, leaving several annoying details regarding all three formations.

Contrast the above-stated problems and omissions associated with both the eastern and the large offset western source proposals with the harmonious combination of data supporting the La Honda-Vallecitos connection:

1. A close and dominant granitic source extending for miles just west of the SAFS and the Vallecitos seaway was exposed throughout the Eocene.

2. Eocene outcrops on both sides of the SAFS — from the La Honda-Palo Alto area, continuing southeast both above and below the town of Hollister, and then extending smoothly into the Vallecitos — make a compelling picture for a graceful, laterally unfaulted early Eocene-Vallecitos seaway connecting the San Joaquin basin with the Pacific.

3. Both the ages and lithologies of the lower Butano and Coalinga sands are a good match.

4. The depositional patterns and thicknesses of all the Coalinga sands not only show a strong genetic connection to each other and a Vallecitos source, but they also are consistent with the expected sequence of sediments discharged from a channel into a basin.

The "Cut-off"

The next event in the proposed sequence is the sudden severing of the marine seaway at the end of early Eocene time. The critical activity and locality that seems most reasonable for the mid-Eocene "cut-off" is tied to the Hollister area, where the Vallecitos channel appears to have narrowed as it bordered or straddled the SAFS for about 15 mi before it connected with the La Honda basin to the west. The disruption could have been caused by a combination of emergence, faulting, and/or uplift on the easterly flank of the Vallecitos channel (effectively shifting the channel axis to the west), or possibly by the major drop in sea level reported for the end of early Eocene time (Haq and others, 1987).

It is reasonable to assume that, after the Vallecitos "cut off", the Pacific Ocean was isolated from the San Joaquin basin for some time, leading to the aforementioned evaporation and subsequent depositional events. Regardless of the amount of time, somehow and in some way, the San Joaquin marine connection was resumed in the middle of the Eocene starting with the Domengine transgression.

Renewal

Any combination of structural-stratigraphic events, including subsidence or rise in sea level, could have facilitated the eventual westerly seaway transfer from the uplifted head of the Vallecitos to a lower San Andreas river channel. Add to this a probable regional tilt to the south, and there is a reasonable scenario for the southerly breakthrough, the follow-up channelizing of the antecedent San Andreas river valley, and the new Pacific Ocean-San Joaquin basin connection, still via the La Honda basin.

Probably the most difficult link in this proposed sequence of events is current evidence for the SAFS-controlled marine channel that guided the resurgent Middle Eocene breakthrough. Figure 3 shows the proposed route, which essentially conforms with the trend of the current trace of the SAFS. As previously mentioned, two of the characteristics of the fault trend are its susceptibility to erosion as well as the high degree of associated structural activity and consequent removal of depositional evidence through time. For these reasons, the San Andreas channel concept may seem a bit convenient, or low on evidence and high on speculation. However, considering the observable erosional and basinal alignments associated with the fault trend throughout the Tertiary, including the current landscape of the Central Coast, the concept is not unusual nor without precedent.

The SAFS is associated with or has controlled:

1. The current topography through the central portion of Central California. A modest rise in sea level (or subsidence) would effectively result in about a 100-mi-long marine arm extending from the San Francisco Bay to south of Hollister. A companion arm to the west would cover an equal distance southeast from Monterey Bay to the Cholame Valley on the SAF.

2. Structural restoration of the Salinas Valley to Plio-Pleistocene time by removing the easterly uplift of the Gabilan Mesa. This demonstrates that much of the Salinas River system flowed south and then east to join the SAFS in the vicinity of the Cholame Valley, where it then followed the northwesterly course of the fault to the Hollister area (Baldwin, 1963). Figure 7 shows the still-visible erosional course of this north-flowing Early Pleistocene segment that closely matches the same course as the postulated San Andreas channel, from Cholame to Hollister.

3. The Waltham Canyon trough (the marine Pliocene connection to the San Joaquin basin). With a strikingly similar configuration to the proposed channel, the trough follows the fault more than 60 mi through a portion of the same area (Figure 8) (Allen, 1946).

4. The northern extension of the Upper Miocene (Bitterwater) basin deep, which straddles the fault in the same vicinity (Figure 9).

5. The presence of a few hundred feet of Domengine strata penetrated in the Sunnyvale Rudolph #1 well (Sec.4, T.18S, R.9E) in the Bitterwater area. Although small in area, these strata have important implications in the reconstruction of Middle and Upper Eocene history because they are located within, and are supportive of, a postulated Middle Eocene channel freeway.

The above examples clearly illustrate the control the SAFS had over not only erosion but, also the alignment and timing of depositional events. Regardless of specifics concerning the exact cause and course of the eventual connection, the proposed San Andreas drainage system was in place and waiting for the breakthrough to guide the subsequent Upper Eocene marine invasion into the southern San Joaquin basin.

The La Honda-Point of Rocks Connection

The prevailing view for the Point of Rocks source terrain is essentially the greater Gabilan. This view, however, requires reconstruction of the Late Eocene paleogeology placing the La Honda basin opposite the Point of Rocks-Kreyenhagen deposits — in effect assuming that these two basins now separated by 180 mi were cogenetic or cojoined as one basin in the Late Eocene (Clarke, 1973).

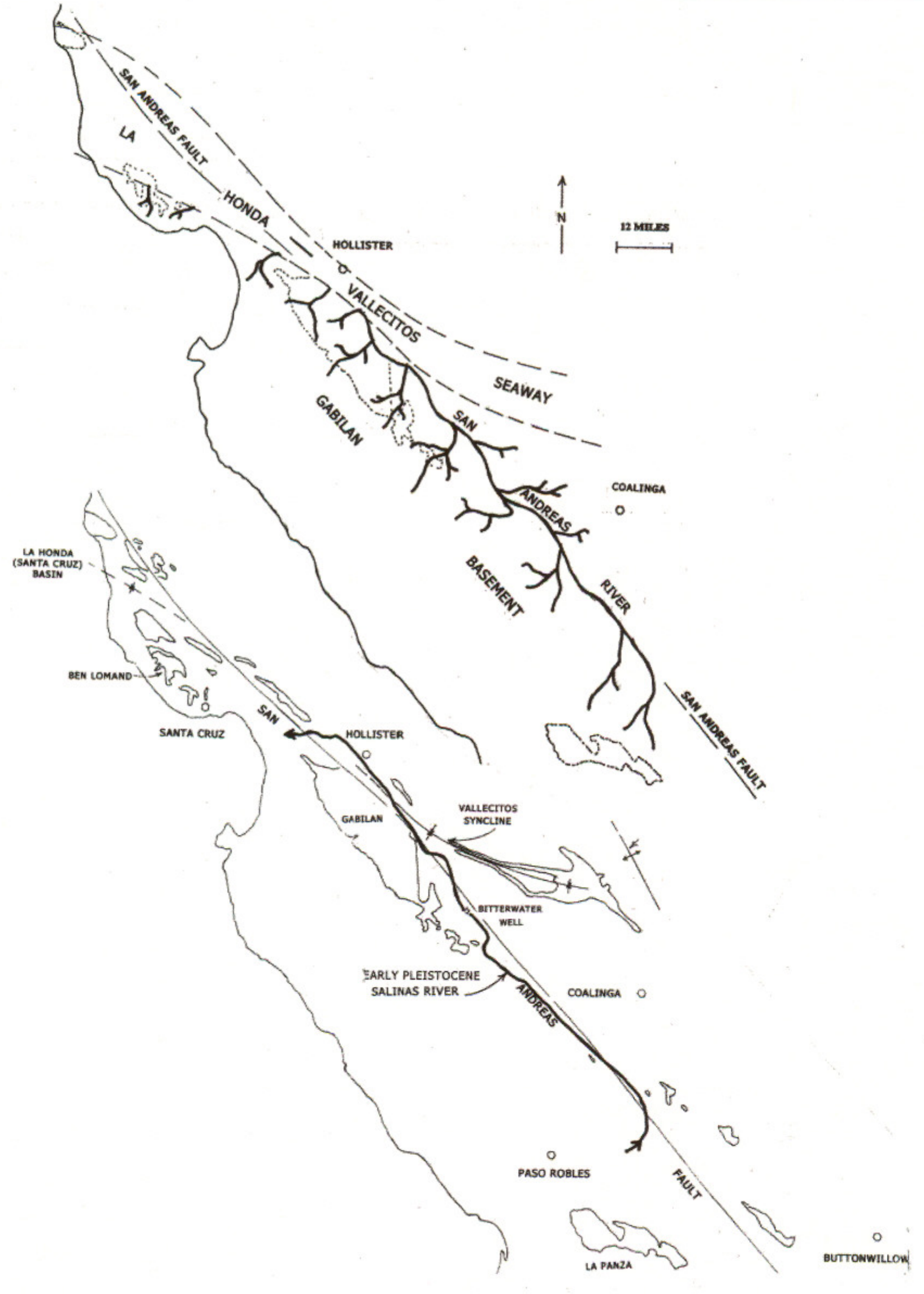

Figure 7

EARLY PLEISTOCENE

Course of the Salinas River Matches Closely the Proposed Early Eocene River (Figure 3)

Figure 7. Maps showing similarities of the proposed Early Eocene San Andreas fault-controlled drainage (top) and the Early Pleistocene San Andreas-defined Salinas river (bottom) — evidence of historical precedent for the proposed concept.

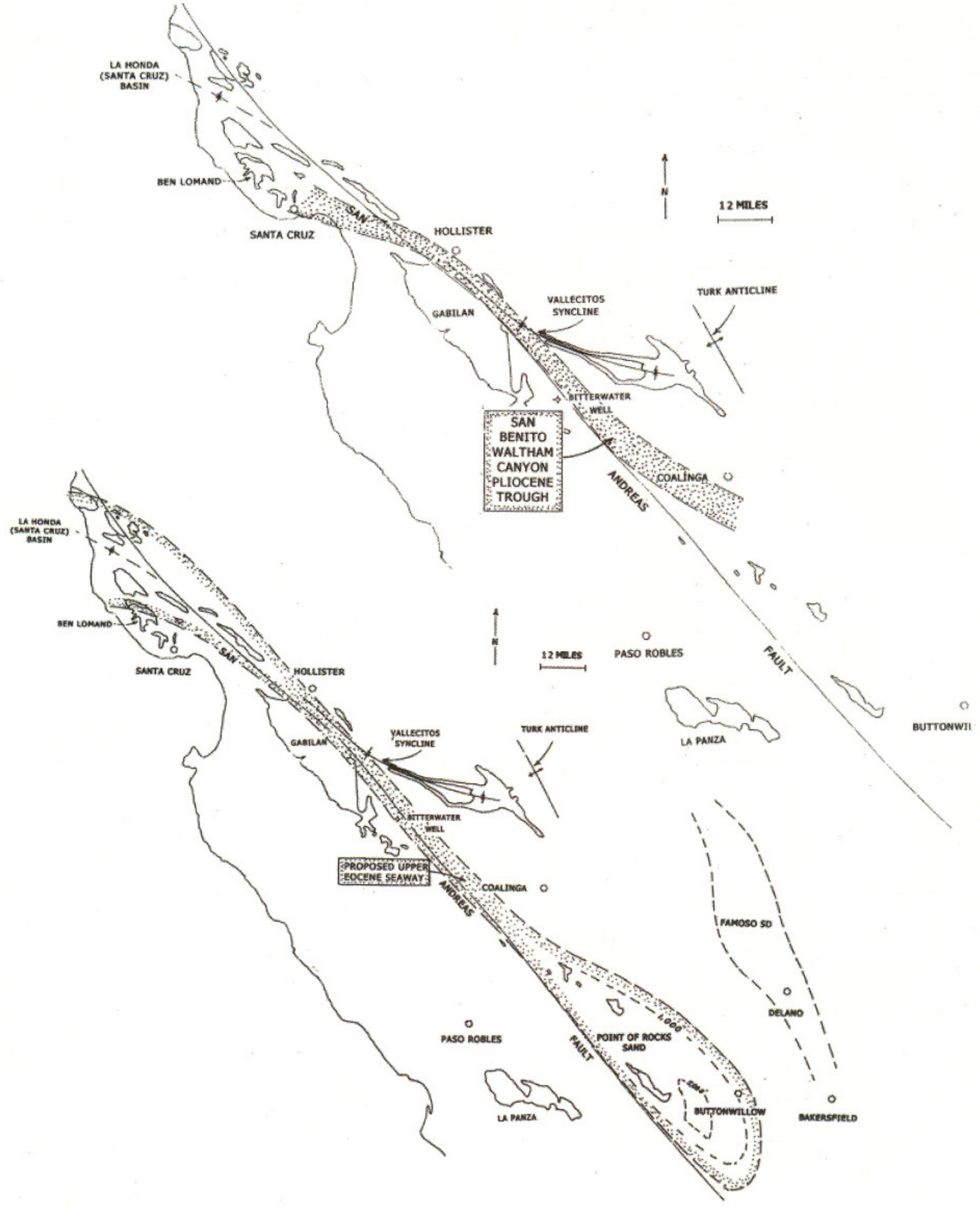

Figure 8

Similarity in Configuration and Relationship to the San Andreas Fault of the Proposed Upper Eocene Seaway and the Pliocene Waltham Canyon Trough

Figure 8. Maps showing examples of the close relationship between the San Andreas fault and deposition during the Pliocene (top) and Late Eocene (bottom), and the similarity (in both configuration and proximity to the fault) between the proposed Late Eocene seaway and the Pliocene trend. Note the pronounced parallelism between the fault and much of the Pliocene strait that connected the San Joaquin basin with the Pacific Ocean.

A La Honda-Point of Rocks connection is widely accepted; only the nature of the connection is disputed (i.e., areal juxtaposition versus the seaway proposed in this paper). The juxtaposed or one-basin proposal raises several concerns. The upper Eocene Butano and Point of Rocks of the two basins correlate lithologically; but there is weak or controversial evidence of any Lower Eocene Butano in the Upper Eocene Point of Rocks depocenter (Almgren and others, 1988). Furthermore, it has not been made clear where, if not the Point of Rocks area, an easterly equivalent of the Lower Eocene portion of the Butano sand might be located.

The juxtaposed or one-basin scenario should not only have a good lithologic and common source correlation, but also a similarity of, or shared, structural-stratigraphic activity. In this regard, there seems to be no cross-fault tie of the Domengine between the now-severed basins. East of the fault, the basin-wide Domengine unconformity represents one of the more dramatic events in California's geologic history. However, in the La Honda basin, or proposed western portion of the San Joaquin basin, deposition throughout the Eocene appears to have been uninterrupted (Cummings and others, 1962). In other words, neither the Domengine unconformity nor the Lower Eocene Butano sands have cross-fault ties that fit the 180-mi-displacement required in the one-basin proposal.

Another discrepancy, or omission from most current reports, regards early and upper Eocene orphan outcrops located on the east side of the SAFS, just west of Stanford University. The age and lithology of these exposures

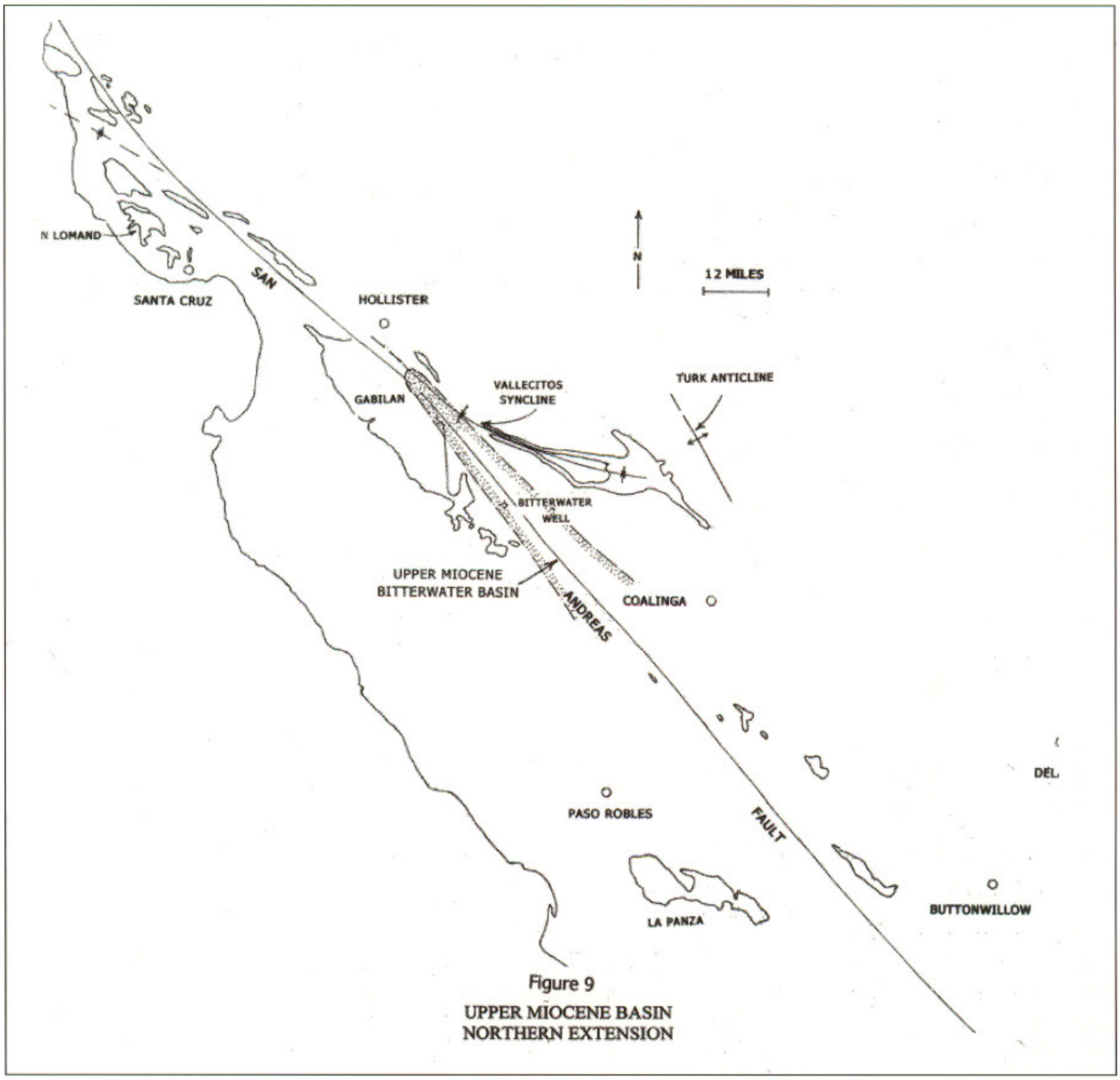

Figure 9. Map showing the axis of the Late Miocene Bitterwater basin and the bisecting San Andreas fault — more evidence of the profound and continuing relationship between the fault and deposition. Note that no lateral offset of the basin is indicated.

match those of the Butano directly across the fault (Dibblee, 1966; Page and Tabor, 1967; Gilbert, 1943; McLaughlin and others, 2001); but the sands do not compare very well lithologically with the proposed German Rancho connection 200 mi to the north.

The cross-fault Lower Eocene age discrepancy, the absence of a Middle Eocene Domengine unconformity in the La Honda basin, and the unexplained orphaned outcrops all represent problems associated with the large lateral displacement proposal. These problems are all neatly resolved by embracing the existence of a Gabilan-sourced La Honda-Vallecitos-Coalinga seaway during the Early Eocene, followed by the renewed, rerouted southern La Honda-"San Andreas" seaway that was the marine conduit for the Middle Eocene Domengine and the Upper Eocene Point of Rocks sands.

Summary

It is possible that some of the deepwater Cantua and some of the Gatchell sands may have been derived from the Sierra provenance, and that some of the Cantua sands were transported west by turbidity currents, as proposed by some researchers. However, this easterly scenario does not work too well for the shallower Gatchell bar and the even-shallower Yokut fan; and it also does not explain the origin of the peculiar 60-mi-long linear sand deposit in the Vallecitos, or the relationship of this proposed eastern source to a meaningful Lower Eocene marine connection. Nor does it address the sudden termination of the Lower Eocene sands and subsequent absence of sand through the Upper Eocene, as indicated by the presence of Kreyenhagen shale over most of this part of the basin.

Most of the proposed match-ups advocating a source west of the SAFS rely on large right-lateral offsets. Taken individually, these lateral correlations are in many cases partially compelling; but age and stratigraphic and lithologic unity between different cross-fault correlations are often lacking or omitted, and there seems to be a breakdown of symmetry when attempting to arrange the different connections in sequence through time. Also, neither the role of the Domengine unconformity in the proposed basin correlations nor the origin of salt has been considered in most proposals.

For the basin and source connections presented here, the Lower Eocene outcrop alignments support the interpretation of an essentially unfaulted La Honda/Vallecitos marine channel, with the source, lithologies, and ages of all subject sands correlating west to east across the fault and all this continuing in smooth sequence with the proposed transition of the Lower to Upper Eocene sand deposition from north to south. In addition, the close geographical association of the two proposed marine seaways with the bordering Gabilan obviates the need for any large-scale lateral fault movements to account for either a shared sand source or the proposed garden-variety structural-stratigraphic events advanced to explain the dramatic Middle Eocene channel diversion that initiated the Late Eocene San Joaquin basin sedimentation. Finally, a reasonable explanation for the environment and origin of salt in the southern San Joaquin basin, the Domengine unconformity, and the extraordinary contrast in depositional depth (shoreline and bathyal) between the Domengine and overlying Kreyenhagen sediments, has been offered as a comprehensive chapter in this "Tale of Two Eocene Sands."

Acknowledgments

At the conclusion of this study, it occurred to me that any geologic report, and particularly one that involves California and the SAFS, is truly never finished — that in many ways it is really a work in progress. Consider this at least a progress report with special thanks to several of my contemporary and knowledgeable geologist friends who have given of their time and intellects to read and comment on this paper as it developed: Alvin A. Almgren, David C. Callaway, Frank B. Cressy, Jr., Nat H. MacKevett, Rodney Nahama, David E. Olsen, Robert H. Paschall, Phillip L. Ryall, and Otto Hackel. Their contributions were many and often vital. Al Almgren's guidance regarding some critical paleogeology was particularly helpful. In no instance is it implied that the acknowledged necessarily agreed with any or all of the concepts presented in this paper. Finally, regarding the work in progress aspect, I continue to welcome comments, pro or con, that might inspire or require another progress report.

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