THE ROLE OF ANTECEDENT RIVERS IN SHAPING THE ORANGE/LOS ANGELES COASTAL PLAIN

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ABSTRACT

During the arid climate of the interglacial Sangamon Age, six small ephemeral rivers flowed to the coast across the Orange/Los Angeles Coastal Plain. These were the Los Angeles, Los Cerritos, San Gabriel, Bolsa Chica, Santa Ana, and Newport rivers. As the arid climate of the Sangamon gave way to the glaciopluvial climate of the Wisconsinan Ice Age, the small ephemeral rivers were gradually transformed to very large perennial ones with enormous erosive power. During this same transition period, tectonic upwarping along the Newport/Inglewood fault zone began producing a ridge that rose above the Orange/Los Angeles Coastal Plain. That ridge is herein named the Newport/Inglewood Ridge. The ridge stretched from Beverly Hills in the north to the San Joaquin Hills in the south and transected all six rivers.

Five of the rivers were successful in eroding channels into the ridge as it was rising beneath their courses. Thus, by definition, these rivers are antecedent ones and the channels they cut through the ridge are water gaps. Rapid upwarping of the ridge on the north side of Signal Hill caused the Los Cerritos River to be diverted to the San Gabriel Water Gap Channel leaving behind the Los Cerritos Wind Gap.

Beside the increased erosive power of the rivers generated by the Ice Age rains, the erosive power was augmented by the drop in sea-level that accompanied the Ice Age. Indeed the lowered sea-level lowered base level for all rivers flowing to the sea world-wide. This change in conditions required the rivers on the Orange/Los Angeles Coastal Plain to begin entrenching their channels to bring their long profiles into new equilibrium with the lower base level. This set of conditions is contrary to the views of some investigators who have asserted that the Santa Ana River not only cut its own water gap channel but switched its course laterally so as to cut the Newport and the Bolsa Chica water gap channels as well. No evidence could be found to support such an assertion.

As the glaciers waned at the close of the Wisconsinan Ice Age, sea-level rose until ocean water began flowing inland within the water gap channel, pushing the mouths of the rivers inland at least 2 miles from the coast. At the same time, coastal wave erosion was eating into the seaward ends of the water gap channels of the Bolsa Chica, Santa Ana, and Newport Rivers as well as the edge of the Newport/Inglewood Ridge between the river mouths. This erosion process produced the modern wave-cut bench and sea cliff along this stretch of the Orange County coast.

The sediment-laden rivers built deltas that eventually filled the water gap channels to sea-level with terrigenous sediment thereby pushing the mouths of the rivers out to the modern coastline once more.

INTRODUCTION

Late Pleistocene climate changes and tectonic activity on the Newport/Inglewood fault zone interacted to produce significant landscape changes on the Orange/Los Angeles Coastal Plain. The climate-related processes involved changes in rainfall, changes in sea-level, with changes in shoreline positions, whereas the tectonic processes mainly involved localized upwarping along the trace of the Newport/Inglewood fault zone. The upwarping may have begun as early as Sangamon time, but was most intense, though probably episodically so, during Wisconsinan time. Pluvioglacial climate change and related processes continued more or less episodically throughout the Pleistocene Epoch, but in this paper the concentration is on the events since the beginning of the Sangamon Interglacial Age (Fig. 1).

THE RIVERS

Six different rivers flowed unimpeded in well-developed courses to the sea across the Orange/Los Angeles Coastal Plain at least since the Pleistocene Sangamon Interglacial Age. These rivers are, from north to south, the Los Angeles, Los Cerritos, San Gabriel, Bolsa Chica, Santa Ana, and Newport (Fig. 2).

THE FIRST TRANSITION PERIOD

During the transition to the Wisconsinan Glacial Age, the rainfall level in Southern California increased significantly to a level comparable to that along the Pacific Northwest coast today where, in some locales, the rainfall averages 80 inches annually. This climate change transformed the former small Sangamon ephemeral rivers in Southern California into very large Wisconsinan perennial rivers possessing enormous erosive power. These rivers were more like those that we see today flowing to the coast in the Pacific Northwest.

THE NEWPORT/INGLEWOOD RIDGE

During this same transition period the terrane along the Newport/Inglewood fault zone was being tectonically upwarped, creating a linear ridge standing above the Orange/Los Angeles Coastal Plain. The ridge eventually extended from Beverly Hills in the north to the San Joaquin Hills in the south. The ridge, herein named the Newport/Inglewood Ridge (new name), ultimately reached up to a mile wide with topographic relief that reached to several hundred feet above the surrounding Orange/Los Angeles Coastal Plain (Fig. 2).

The resultant ridge transected the courses of the six major rivers that were flowing to the sea across the Orange/Los Angeles Coastal Plain. In order for these rivers to maintain their courses to the sea without being diverted, they had to begin entrenching channels in the ridge as it was rising above the surface of the surrounding plain. All six rivers commenced the entrenchment process but only five of these rivers were successful. The ridge would have been virtually unbroken had it not been for channels cut through it by five of the six big rivers during the Wisconsinan Ice Age (Fig. 3).

All of the breaks in the continuity of the ridge are water gap channels except for the topographic depression at Anaheim Bay. The Anaheim Bay depression may simply be a section along the Newport/Inglewood fault zone that did not undergo the same degree of tectonic upwarping that occurred elsewhere along its trace.

THE LOS CERRITOS WIND GAP

The Los Cerritos River during this period had entrenched a well-defined channel across the crest of the Newport/Inglewood Ridge just north of Signal Hill, but could not sustain its position at that location due to the rapid local upwarping of the ridge. Consequently, the Los Cerritos River was diverted to the south, leaving behind a well-defined notch across the crest of the ridge that contained no through-flowing stream. The abandoned channel is here given the name, Los Cerritos Wind Gap (Fig. 4). The diverted Los Cerritos River subsequently entered the San Gabriel River Water Gap Channel where it passed through to the ocean, possibly without converging with that river. The present day Los Cerritos Channel is a vestige of the former Los Cerritos River.

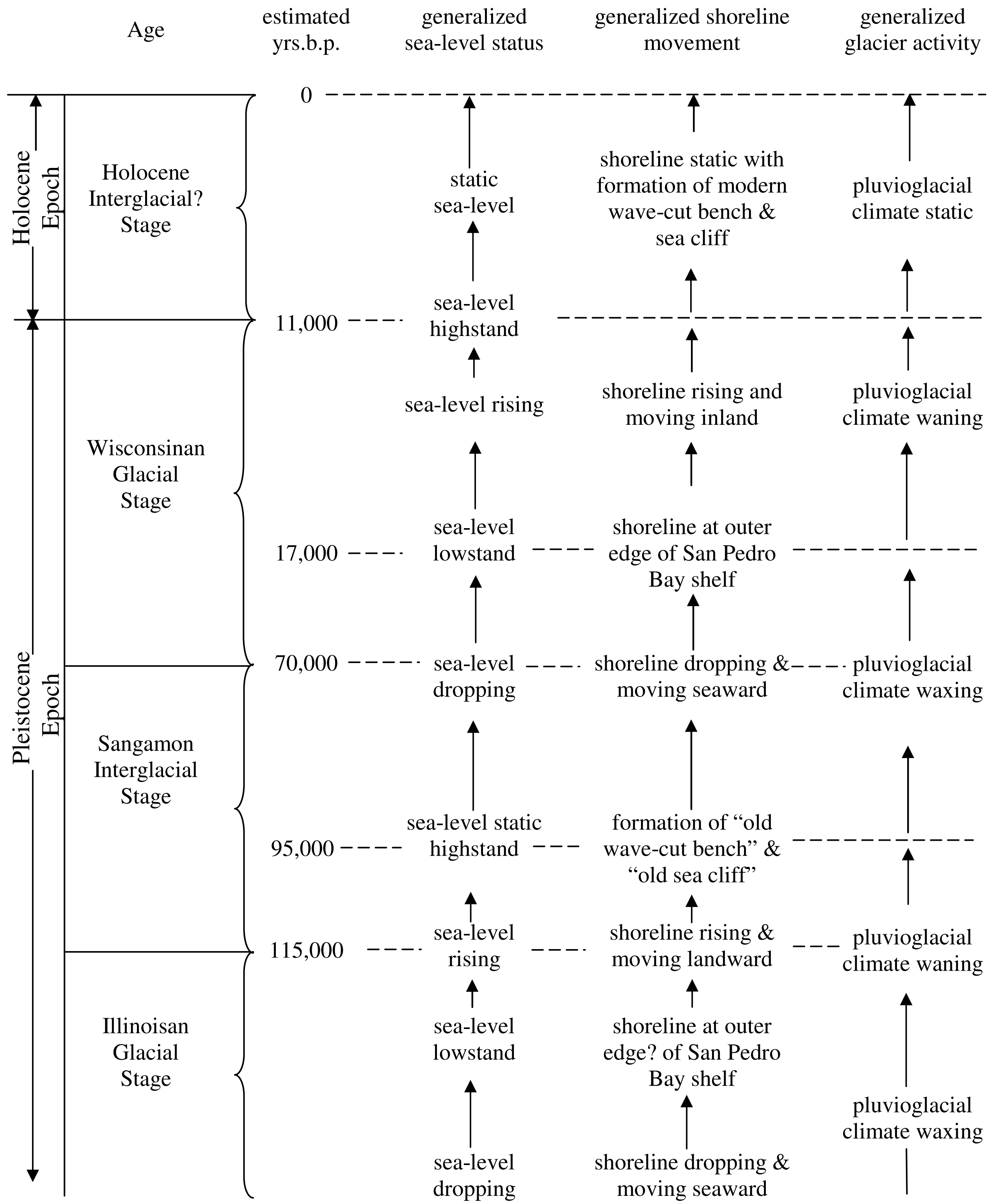

Figure 1. The periods of transition and standstill of the environmental processes operating on the Orange/Los Angeles Coastal Plain during late Quaternary time are illustrated graphically. These processes include changes in sea-level, changes in shoreline position, and changes in the pluvioglacial climate that controlled the flow volume of the antecedent rivers and consequent streams on the Orange/Los Angeles Coastal District.

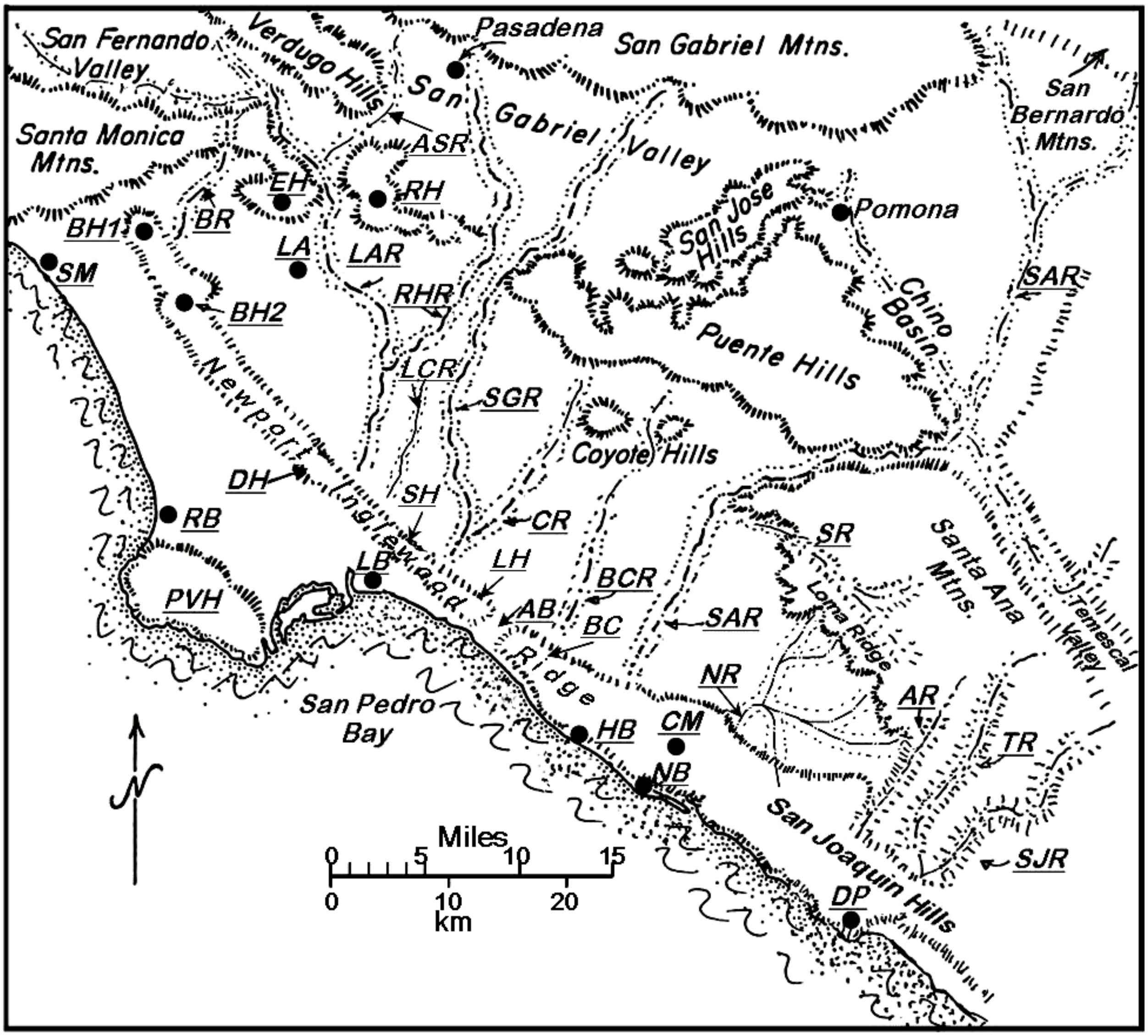

Figure 2. Illustrates the continuity and linearity of the Newport/Inglewood Ridge as it would have appeared on the Orange/Los Angeles Coastal Plain if it had it not been transected by water gap channels. Also are the locations and identities of the rivers that would have been blocked by the ridge that was rising beneath their courses had they not had the power to entrench their channels in the growing ridge. The Orange/Los Angeles Coastal Plain extends from the Santa Monica Mountains in the North to the San Joaquin Hills in the South and from the Repetto Hills/Puente Hills/Santa Ana Mountains on the east to the Palos Verdes Hills on the west.

Index to abbreviations: AB, Anaheim Bay; AR Aliso River; ASR, Arroyo Seco River; BC, Bolsa Chica; BCR, Bolsa Chica River; BH1, Beverly Hills; BH2, Baldwin Hills; BR, Ballona River; CM, Costa Mesa; CR, Coyote River; DH, Dominguez Hills; DP, Dana Point; EH, Elysian Hills; LA, Los Angeles; LAR, Los Angeles River; LB, Long Beach; LCR, Los Cerritos River; LH, Landing Hill; NR, Newport River; PVH, Palos Verdes Hills; RB, Redondo Beach; RH, Repetto Hills; RHR, Rio Hondo River; SAR, Santa Ana River; SGR, San Gabriel River; SH, Signal Hill; SJR, San Juan River; SM, Santa Monica; SR, Santiago River; TR, Trabuco River. Note: all of these streams are shown as rivers because it was during the Wisconsinan Ice Age when all the identified stream flows were large enough to be considered rivers.

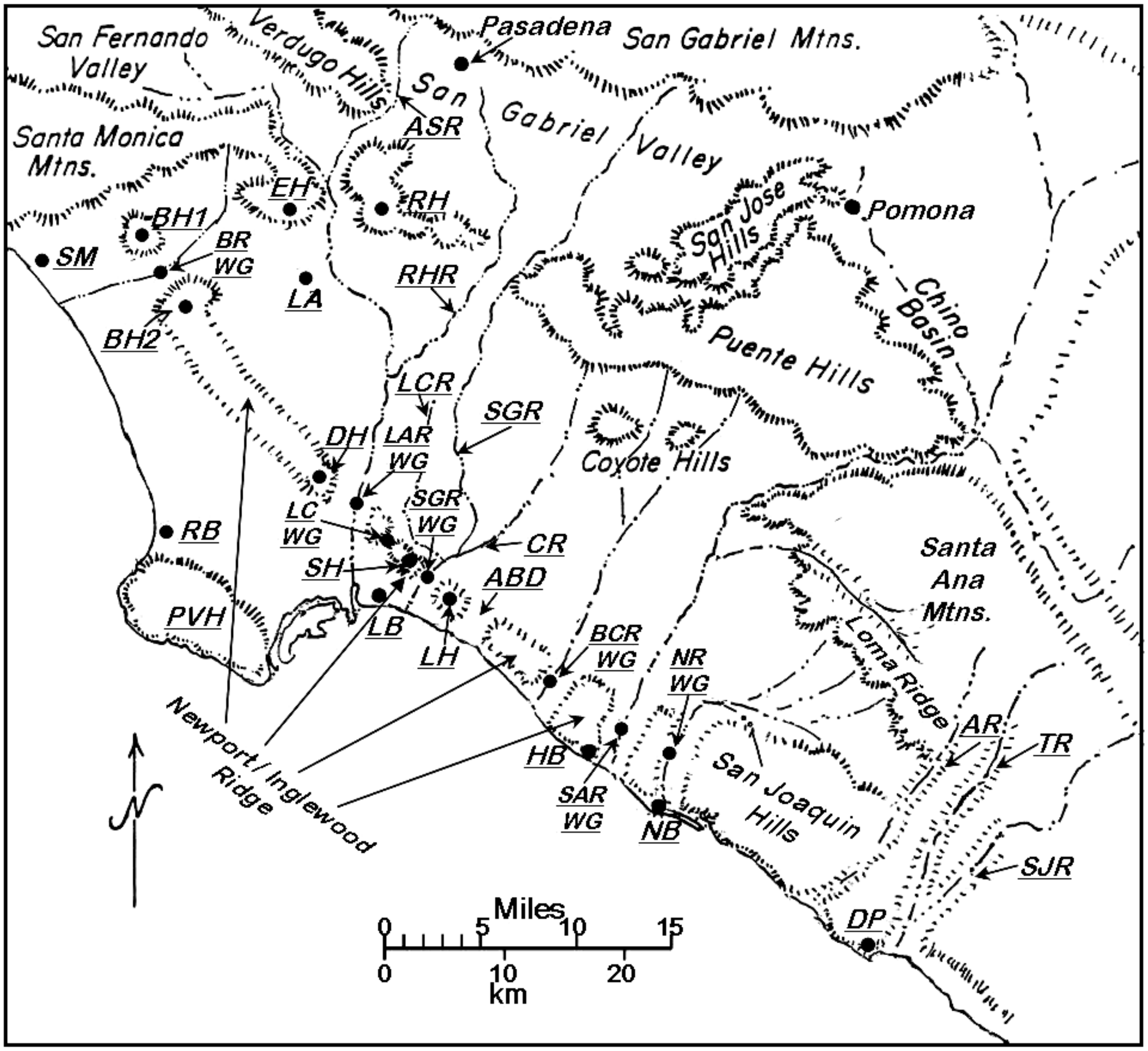

Figure 3. Locations of the water gap channels that were entrenched in the Newport/Inglewood Ridge by the antecedent rivers that flow to the coast on the Orange/Los Angeles Coastal Plain.

Index to abbreviations. The water gap channels are as follows: ABD, Anaheim Bay Depression; BCRWG, Bolsa Chica River Water Gap; BRWG, Ballona River Water Gap; LARWG, Los Angeles River Water Gap; LCRWG, Los Cerritos River Wind Gap; NRWG, Newport River Water Gap; SARWG, Santa Ana River Water Gap; SGRWG, San Gabriel River Water Gap.

The rivers are as follows: AR, Aliso River; BCR, Bolsa Chica River; BR, Ballona River; CR, Coyote River; LAR, Los Angeles River; LCR, Los Cerritos River, NR, Newport River; RHR, Rio Hondo River; SAR, Santa Ana River; SGR, San Gabriel River; SJR, San Juan River; TR, Trabuco River.

Other land marks are as follows: BH1, Beverly Hills; BH2, Baldwin Hills; DH, Dominguez Hills; DP, Dana Point; EH, Elysian Hills; HB, Huntington Beach; LA, Los Angeles; LB, Long Beach; LH, Landing Hill; NB, Newport Beach; PVH, Palos Verdes Hills; RB, Redondo Beach; RH, Repetto Hills; SH, Signal Hill; SM, Santa Monica.

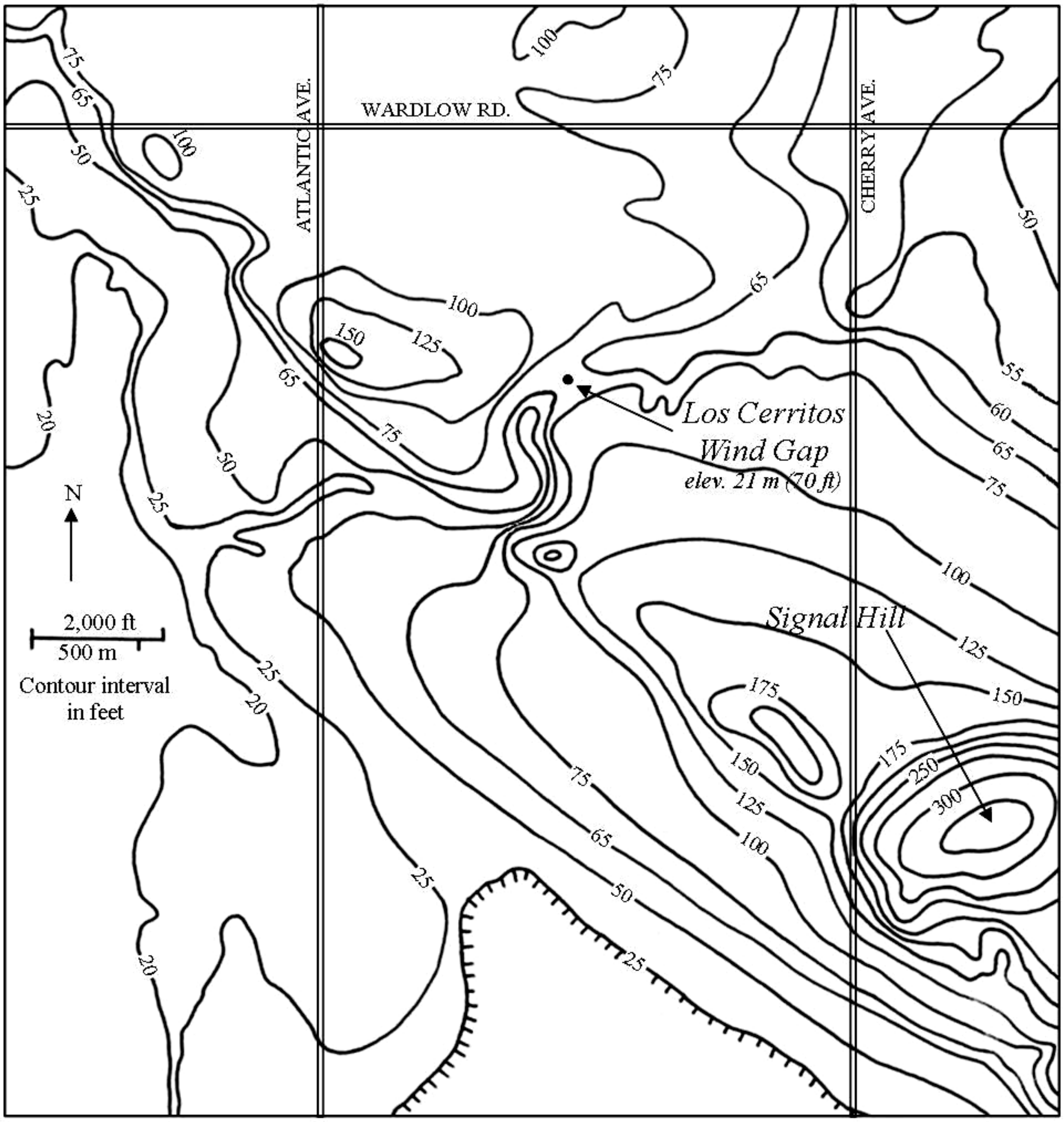

Figure 4. Map of the topography of the Los Cerritos Wind Gap on the northwest flank of Signal Hill. Note the elevation of the drainage divided in the middle of the wind gap at approximately 70ft above sea-level. The wind gap channel was once occupied by the antecedent Los Cerritos River. Subsequently that river was diverted to the San Gabriel Water Gap Channel where it flowed to the sea beside the San Gabriel River. The topography for this map was extracted from the Long Beach, CA., 1949, U.S.G.S. 7.5 min. topographic quadrangle map.

ANTECEDENT RIVERS AND WATER GAP CHANNELS

The five remaining rivers on the Orange/Los Angeles Coastal Plain continued their flow to the coast in spite of terrane along the trace of the Newport/Inglewood fault zone being upwarped beneath their courses. Each of these rivers continued to entrench well-defined channels through the ridge as it was rising beneath their courses. Therefore the rivers are antecedent ones and the channels they eroded through the ridge are water gaps.

It was the formation of the Wisconsinan continental and mountain glaciers, present even in the San Bernardino Mountains of Southern California, which generated an intense Wisconsinan pluvioglacial climate in Southern California. The runoff from the heavy rainfall helped give the rivers the power they needed to entrench their water gap channels in the ridge rising beneath their courses (Colburn, 2003).

The dimensions of the drainage basins for the antecedent rivers are specified in Table 1. For comparison purposes, the dimensions of the consequent streams on the Orange County coast are specified in a similar Table 2. From these tables it may be observed that the drainage basins of the antecedent rivers are an order of magnitude larger than those of the consequent streams in the San Joaquin Hills.

THE SANGAMON SEA-LEVEL

During the Sangamon Interglacial Age, it is estimated that sea-level stood 100 ft higher than today and the shoreline was farther inland along the coast. The growth of the continental glaciers during the transition to the Wisconsinan Ice Age removed such a large quantity of water from the world's oceans that sea-level dropped more than 400 ft below its Sangamon level and up to 300 ft below present-day sea-level.

THE SANGAMON INTERGLACIAL STRATA

The rising crest of the Newport/Inglewood Ridge was composed, for the most part, of poorly lithified, transgressive, shallow-marine beds overlain by progradational fluvial deposits that had accumulated on the Orange/Los Angeles Coastal Plain during Sangamon time. With the exception of the beds of the underlying Monterey Formation, strata along the crest of the Newport/Inglewood Ridge provided very little resistance to the entrenching action of these rivers. These poorly lithified beds, which are equivalent in type and age to the Palos Verdes Formation in San Pedro, are also well exposed in the walls of the Bolsa Chica, Santa Ana, and Newport water gap channels. They also are easily seen in the face of the sea cliff that borders the inland side of Pacific Coast Highway in Newport Beach between the Santa Ana and Newport rivers. The latter beds are resting on the "old wave-cut bench" that formed on the Monterey bedrock during the Sangamon Age high stand of the sea.

THE WISCONSINAN BASE LEVEL

The Wisconsinan drop in sea-level affected the base level of all the rivers and streams that flow to the sea. This meant that all the rivers and streams had to entrench their channels in their own flood plains in order to regrade their longitudinal profiles into equilibrium with the new lower base level. This resulted in an added degree of erosion power to the antecedent rivers.

In summary, it was a combination of the intense rainfall during the Wisconsinan Ice Age, the accompanying drop in sea-level, and the presence of weakly lithified Sangamon strata along the crest of the Newport/Inglewood Ridge made it relatively easy for five of the six rivers to entrench their channels in the landscape that was rising beneath their courses (Fig. 3).

THE NEWPORT RIVER

The Newport River was one of the five rivers that successfully entrenched its channel

Table 1. This table shows the overall size and variation of the antecedent river* basins of the Orange/Los Angeles Coastal Plain. Note that the antecedent river drainage basins are an order of magnitude larger in length and areal extent than comparable parameters for the consequent rivers that flowed to the coast from the ocean side of the San Joaquin Hills (Table 2).

*These streams are referred to as rivers and not streams because they are being judged by the size and vigor of their flow during the pluvioglacial climate of the Wisconsinan Ice Age. It was the heavy rainfall of this period that gave these rivers the power they needed to entrench their channels in the Newport/Inglewood Ridge as it was rising beneath their courses.

**Flow contributions from the following tributaries combined to become a single river, the Newport River, flowing to the Newport coast at least as early as Sangamon time. The tributaries from Loma Ridge are Peters Canyon Cr., Rattlesnake Cr., Hicks Canyon Cr., Bee Cr., Borrego Cr., and Serrano Cr. Coming from the El Toro Plain was San Diego Cr. and from the San Joaquin Hills was Sand Canyon Cr. with its tributaries Shady Canyon Cr. and Bommer Canyon Cr.

	area in sq. miles	length in miles
1. Los Angeles River	843 sq. miles	61 miles
2. San Gabriel River	604 sq. miles	55 miles
3. Bolsa Chica River	113 sq. miles	17 miles
4. Santa Ana River	1,689 sq. miles	56 miles
5. Newport River**	260 sq. miles	20 miles
6. Aliso River	140 sq. miles	16 miles
7. San Juan River	390 sq. miles	24 miles

Table 2. The dimensions of the drainage basins of a representative number of consequent streams that flow to the ocean from the western slope of the San Joaquin Hills between Laguna Beach and Newport Beach. A comparison of these basins with those of the antecedent rivers (Table 1) on the Orange/Los Angeles Coastal Plain shows the basins of the latter to be an order of magnitude larger. These stream channels are deeply entrenched in the seaward flank of the San Joaquin Hills, a process that began as these hills were emerging from the sea. Barrie, et el. (1992, p. 10) estimated, on the basis of uplift rates, that the emergence process began approximately 1,230,000 (1,230 ka) years ago or back to near the beginning of the Pleistocene Epoch.

	area in sq. miles	length in miles
1. Buck Gulley	57.6 sq. miles	3.0 miles
2. Los Trancos Canyon	44 sq. miles	3.1 miles
3. Muddy Canyon	37.7 sq. miles	3.3 miles
4. Morro Canyon	75.4 sq. miles	3.1 miles
5. Emerald Canyon	54.2 sq. miles	3.0 miles
6. Boat Canyon	13.1 sq. miles	0.75 miles
7. B.M. 109 Canyon	7.07 sq. miles	1.0 mile
8. Arch Rock Canyon	15.7 sq. miles	1.0 mile
9. B.M. 18 Canyon	3.14 sq. miles	1.0 mile
10. Laguna Canyon	30 sq. miles	6.5 miles

in the Newport/Inglewood Ridge. At least by the end of Sangamon time, separate streams from Loma Ridge, the El Toro Plain, and the inland side of the San Joaquin Hills converged to form a single river, herein named the Newport River. The Loma Ridge tributaries included Peters Canyon Wash, Rattlesnake Wash, Hicks Canyon, Bee Canyon, Aqua Chinon Wash, Borrego Canyon, and Serrano Creek. These creeks flowed across the El Toro Plain to join San Diego Creek along with the drainages from the inland facing slopes of the San Joaquin Hills. In the latter case, it was the combined flow of Bommer Creek and Shady Canyon Creek that flowed into Sand Canyon Creek and this stream in turn joined San Diego Creek (Fig. 5).

The resultant Sangamon Newport River established a course to the coast through what is now Newport Beach well before tectonic upwarping commenced along the trace of the Newport/Inglewood fault zone.

It was not until the beginning of the Wisconsinan pluvioglacial climate and the drop in sea-level associated with the formation of the great ice sheets of Wisconsinan Ice Age that Newport and Santa Ana rivers were transformed from relatively small ephemeral streams in Sangamon time into powerful agents of erosion in Wisconsinan time. As the two rivers became more powerful, they became capable of entrenching their water gap channels in the Newport/Inglewood Ridge as the ridge began rising beneath their courses during the Wisconsinan Ice Age (Fig. 6). This was a process similar to that which was happening simultaneously with the other antecedent rivers with respect to the formation of their water gap channels (Fig. 3).

It may be difficult to visualize just how different the fluvial processes were in southern California during the Wisconsinan Ice Age given the arid climate and fluvial conditions we observe here today. The best analogue is to apply the pluvioglacial conditions of the Pacific Northwest coast today to Southern California during the Wisconsinan Ice Age. The former presence of these great rivers is evidenced by the great size of the water gap channels (see Summary of Water Gap Channel Dimensions). Clearly the small ephemeral streams we see today in these water gap channels are underfit for the size of the channels within which they flow.

THE LOW LAND INLAND FROM THE NEWPORT/INGLEWOOD RIDGE

The Orange/Los Angeles Coastal Plain immediately inland from the Newport/Inglewood Ridge is lower in elevation than are the mesas that cap the ridge (Fig. 7 and 8). It would have been impossible, therefore, for these rivers flowing seaward across the Orange/Los Angeles Coastal Plain to have climbed up and over the Newport/Inglewood Ridge if the rivers were formed after the ridge was formed. This is why the rivers had to be in place flowing to the sea across the Orange/Los Angeles Coastal Plain prior to the formation of the Newport/Inglewood Ridge and why the rivers needed enough erosive power to cut their water gaps through the ridge.

OTHER INTERPRETATIONS OF THE ORIGIN OF THE WATER GAP CHANNELS

The foregoing interpretation of the origin of the Upper Newport Bay Channel is at variance with several reports that have appeared in geological journals in recent years. One such article is by Stevenson and Emery, 1958, page 10, who say the following on the origin of the Upper Newport Bay Channel. "The pertinent geologic history of the Newport Bay region began in the middle Pleistocene Epoch. The land mass was higher than it is today and the Santa Ana River, with help from other streams, began to carve the incised channel. Test holes drilled near the inlet show the bottom of the river bed to be a maximum of 123 feet below present sea level. Typically the river changed its course several times as it has also done within the past 100 years….."

The authors go on to say (page 10), "The sequence of events leading to the

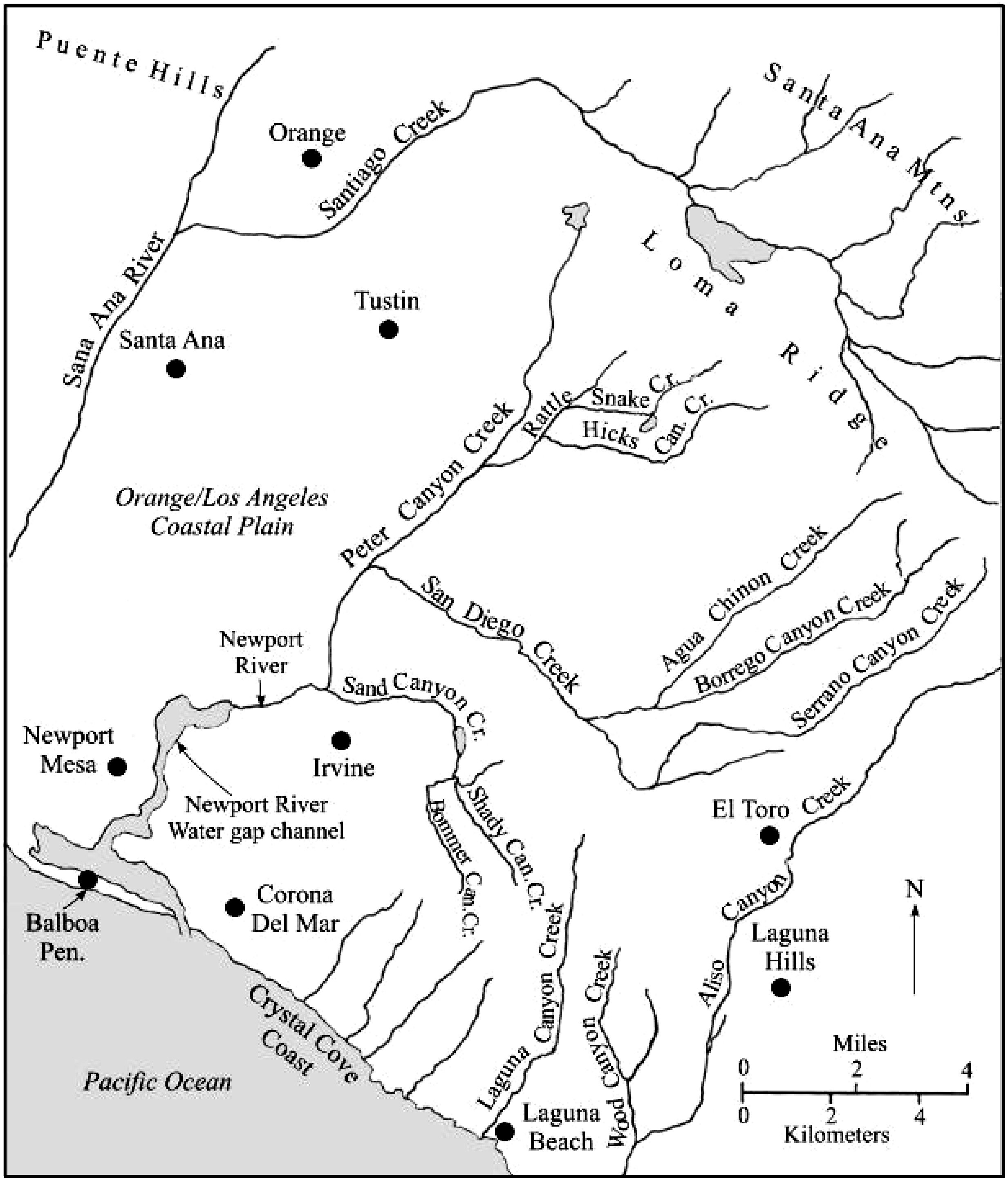

Figure 5. Names, locations, and distribution of the tributary streams that converged at least as early Sangamon time to form the antecedent Newport River. The tributaries from Loma Ridge include Peters Canyon and its tributaries, such as Rattlesnake and Hicks Canyons; San Diego and its tributaries from Loma Ridge such as Agua Chinon and Serrano Canyons; Sand Canyon and its tributaries from the San Joaquin Hills such as Shady Canyon and Bommer Canyon.

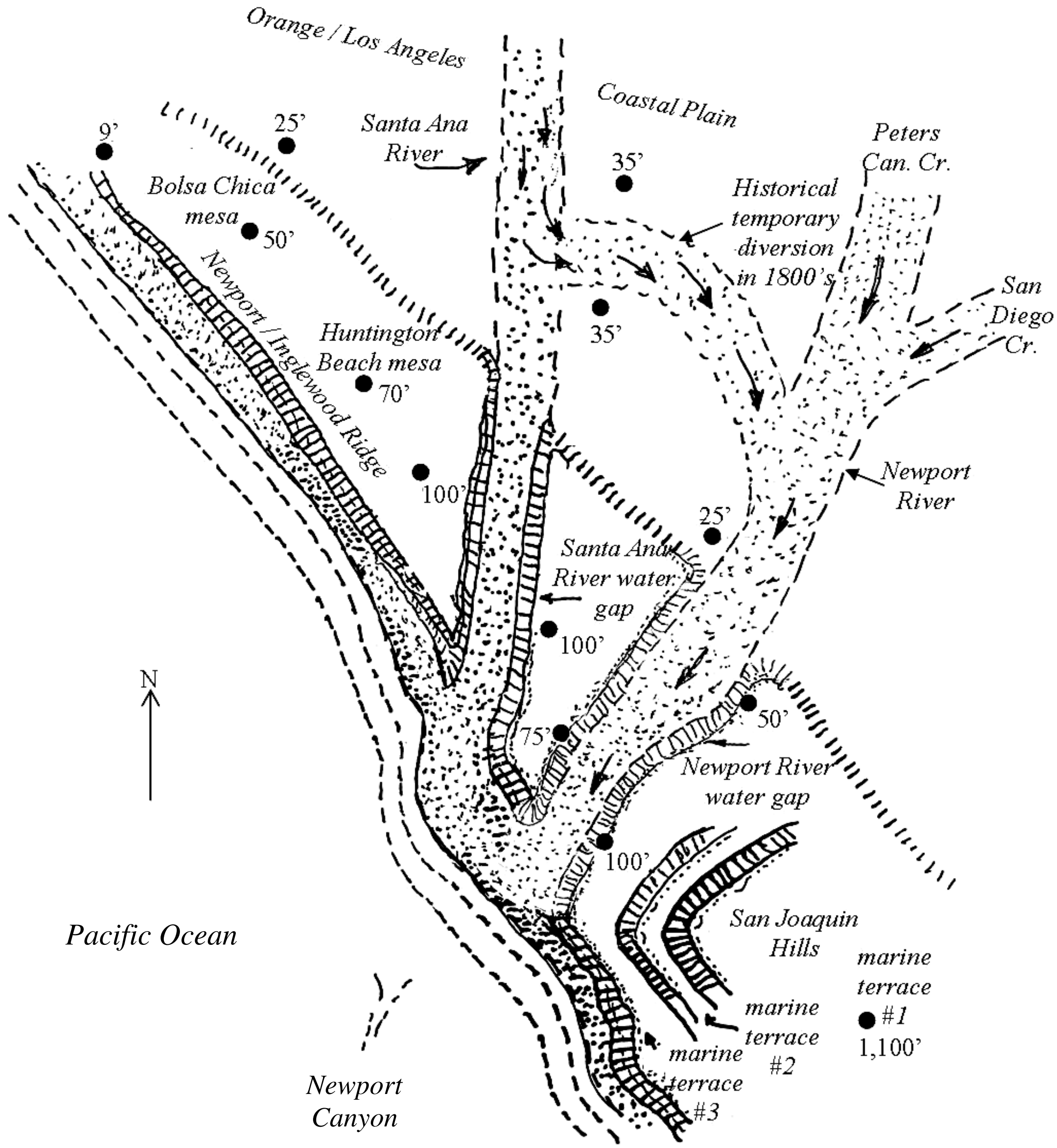

Figure 6. Graphic rendition (not to scale) illustrating geologic and topographic configuration of the separate water gap channels of the antecedent Santa Ana and Newport rivers in their water gap channels in the Newport/Inglewood Ridge. These water gap channels were cut into the ridge during the Wisconsinan Ice Age. The elevations are obtained from the standard U.S.G.S. topographic quadrangle maps of this district.

It was indicated in anecdotal reports of the late 1800s that the Santa Ana River may have left its own course inland from its water gap channel during a flood and entered the head of the Newport River Water Gap Channel. The topography along the inland side of the Newport/Inglewood Ridge would have allowed the flood waters to flow south down hill toward the head of the Newport River Water Gap Channel and to enter it. Subsequently the Santa Ana River was restored to its own channel and held there behind dike barriers. This event had no relationship to the origin of Newport River Water Gap Channel because that channel was formed by its own antecedent Newport River at least during the Wisconsinan Ice Age. The elevations are obtained from U.S.G.S. 7.5 min. quadrangle maps of the district. These are: Newport Beach, CA., 1949; Laguna Beach, CA., 1948; Orange, CA., 1949; Tustin, CA., 1948.

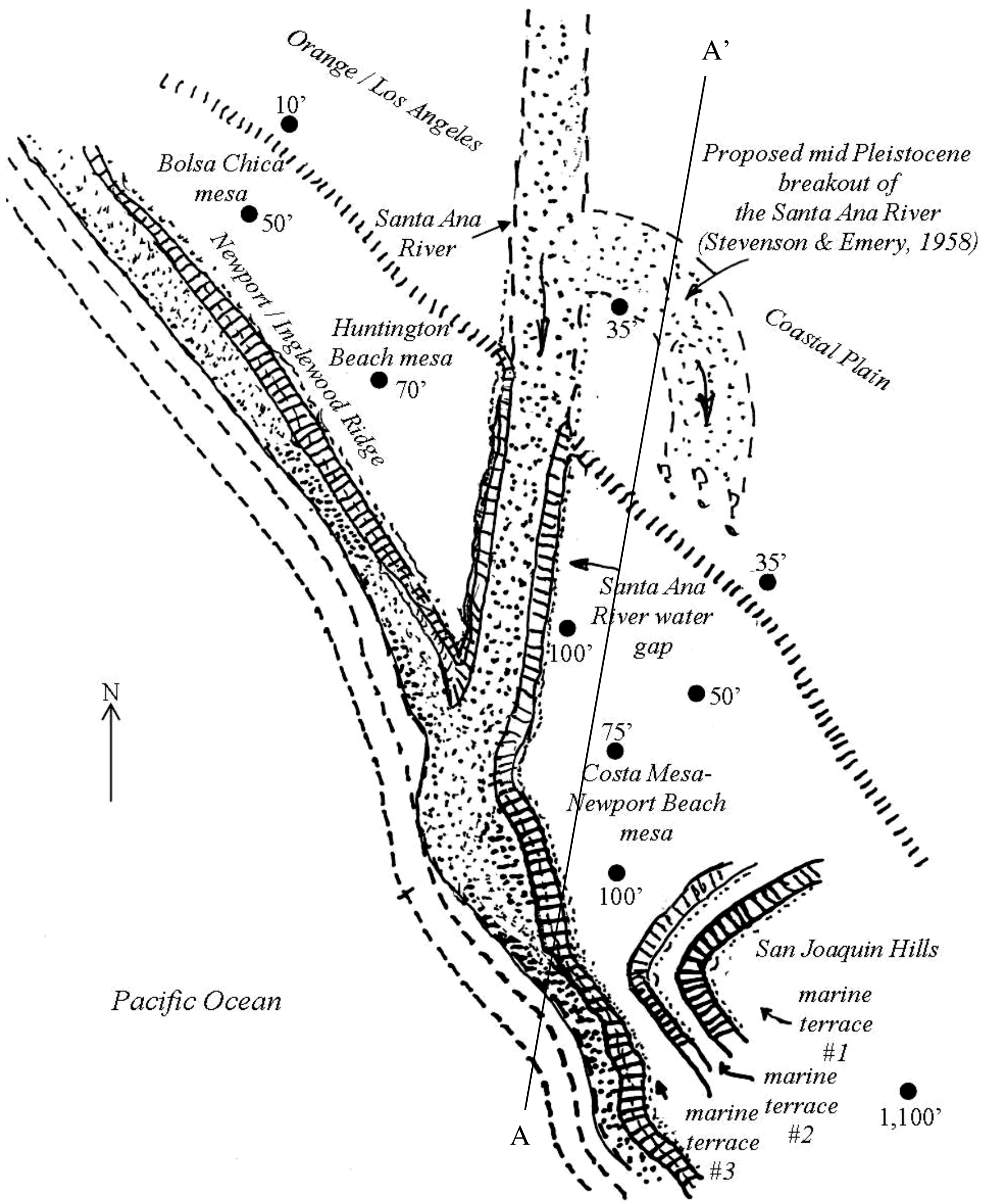

Figure 7. An illustration of the geologic conditions that stand in the way of the making the Stevenson and Emery, 1958, scenario acceptable. First, as can be seen on the map, if the Santa Ana River breaks out of its well established channel it must do so upstream from its water gap channel. Second, if the Santa Ana River heads south from its own channel it must do so on the inland side of the Newport/Inglewood Ridge. If the river goes south and then tries to turn toward the coast to form the Upper Newport Bay Channel its path is going to be blocked by the height of the Newport Ridge as can be seen by the elevation values plotted on this map. These elevation values are obtained from the standard U.S.G.S. 7.5 min. topographic quadrangle sheets of the district. These maps are as follows: the Orange, CA., 1949; Anaheim, CA., 1949; Laguna Beach, CA., 1948, Tustin, CA., 1948, and Newport Beach, CA., 1949.

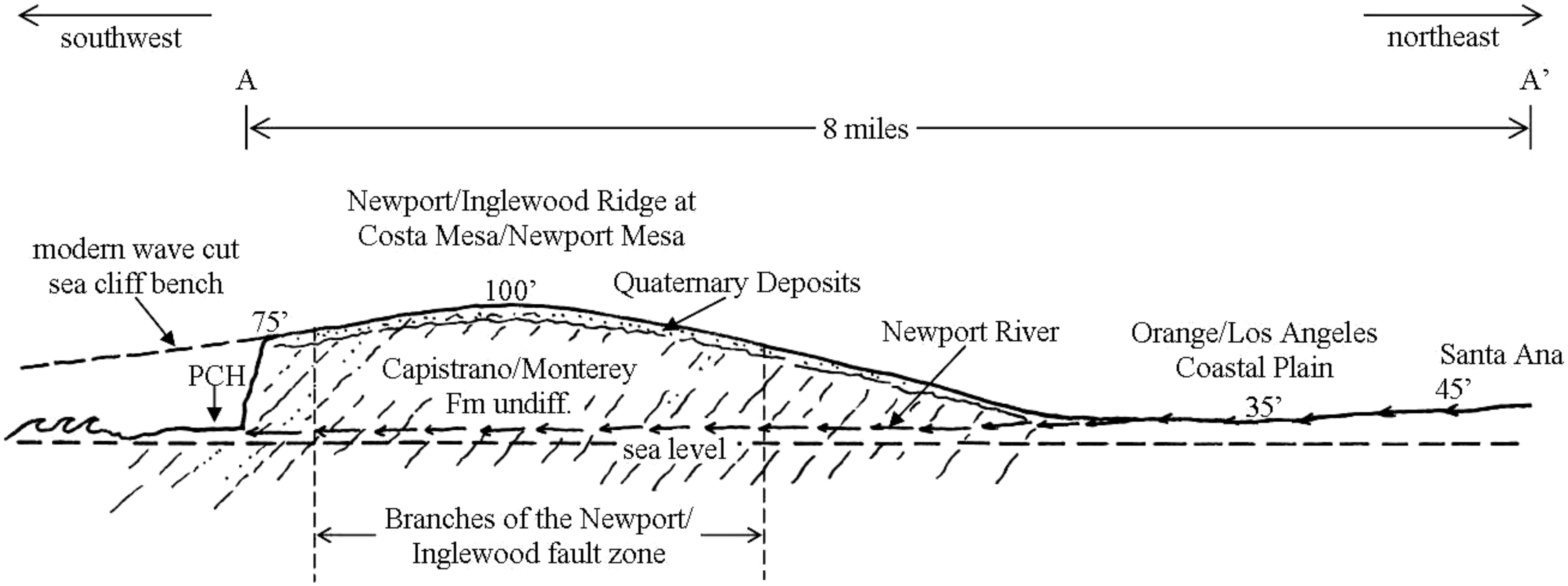

Figure 8. The geologic and topographic cross-section depicts (not to scale) the topographic relief of the Newport/Inglewood Ridge that lies between the Orange/Los Angeles Coastal Plain and the Newport coast. The elevation values are from the standard U.S.G.S. quadrangle maps of the district.

Illustrated beneath the topographic profile is a generalized version of the geologic units exposed in the walls of the Newport River Water Gap Channel as well as their structural configuration. The approximate interval that defines the zone of fault traces is bracketed. This diagram illustrates why any river attempting to flow to the coast from the Orange/Los Angeles Coastal Plain inland from the Newport/Inglewood Ridge would be blocked by the height of the ridge.

Also shown is the manner in which Holocene wave attack has eaten into the ocean end of the water gap channel and the edge of the Newport/Inglewood Ridge, producing a modern wave-cut bench and seacliff.

Elevations were obtained from standard U.S.G.S. 7.5 min. quadrangle maps of the district. These are: Newport Beach, CA., 1949 and Laguna Beach, CA., 1948.

development of the deep channel in the Bay region likely began in the middle of the Pleistocene Epoch when sea level was more than 100 feet lower than today and the Santa Ana River meandered across a gently sloping alluvial plain and was beginning to erode a course through the present Bay area" (Fig. 9).

Stevenson and Emery (1958) in their Fig. 37, page 100, shows the Santa Ana River in 1894 back in its own water gap channel between Huntington Beach and Costa Mesa. The authors did not explain how the Santa Ana River made this reverse shift of course.

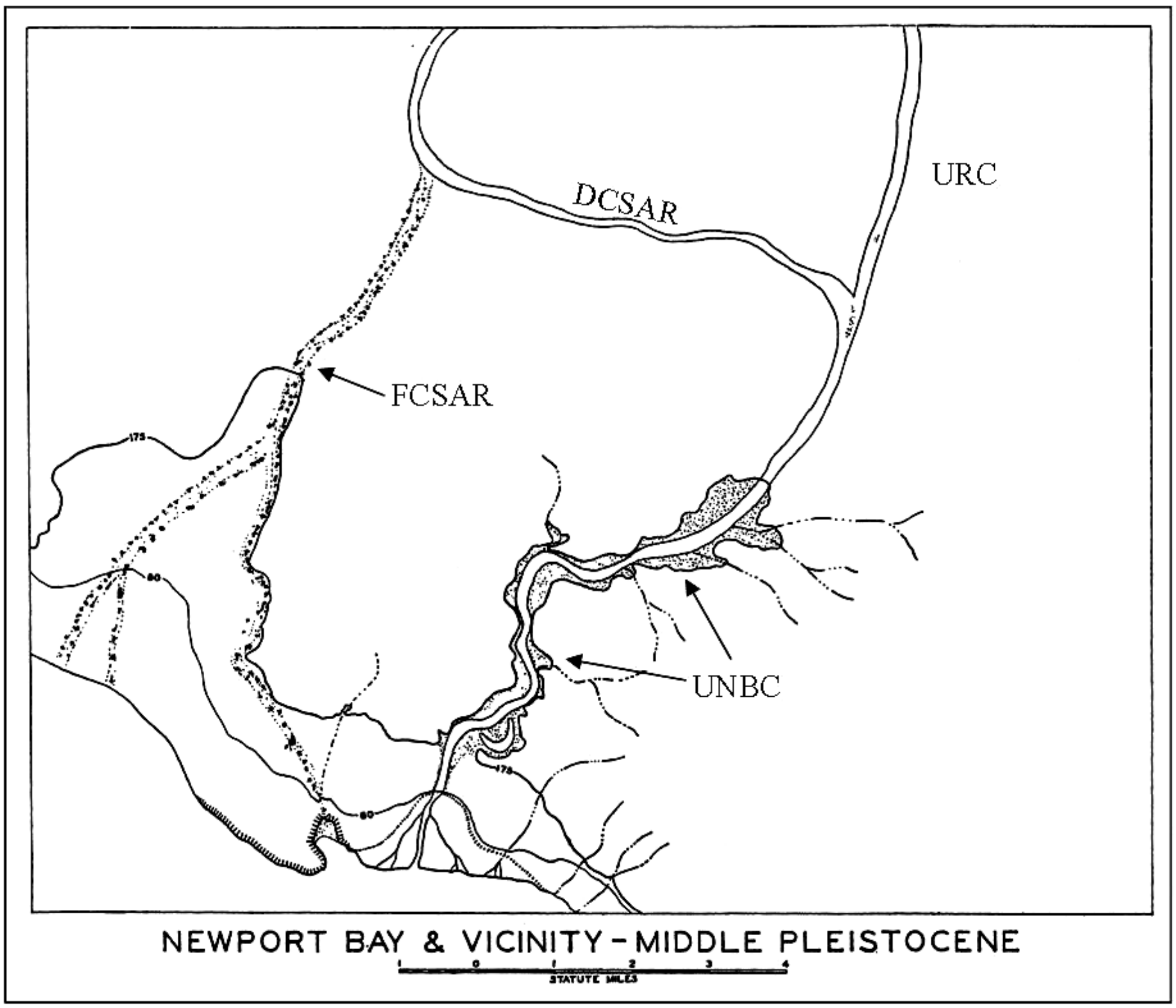

Figure 9. This map appears as figure 16, page 88 in Stevenson and Emery, 1958. The caption for this map reads as follows: "A diagrammatic sketch of the Newport Bay area during the middle Pleistocene. The Santa Ana River is depicted here in the process of carving the Newport Bay Channel after being diverted from an earlier course. The sea level during this time is indicated as being 175 feet below the present level."

These river courses were not labeled by the authors so labels have been added for clarity as follows: the former course Santa Ana River is FCSAR and is shown on the map as stippling; the diverted course Santa Ana River is labeled DCSAR; unknown river course shown joining the Santa Ana River inland from Upper Newport Bay Channel was not identified by the authors in URC. The Upper Newport Bay Cannel is UNBC.

On page 139 in their 1992 paper, Moran and Wiebe asserted, "Concurrent with the post-Sangamon decline in base level, an ancestral Santa Ana River carved significant valleys across the coastal plain of Orange County. The river also incised well-defined gaps through the slowly rising Newport/Inglewood uplift at Alamitos Gap, Sunset Beach, Bolsa Chica and at Santa Ana or Talbert Gap, in Huntington Beach."

Not include in their paper is the geologic reasoning they used to develop their scenario on the creation of multiple water gap channels by the Santa Ana River. They stated that the shifting of the Santa Ana River occurred during post-Sangamon decline in base level (this means during the Wisconsinan lowstand of sea-level). Such a drop in base level would have caused the Santa Ana River and the other four antecedent rivers to entrench themselves in their floor plains. When such entrenchment occurs the rivers become confined to their channels and are no longer able to shift laterally on their flood plains, as suggested by these authors.

Lajoie and Ponti (1992, page x) asserted, "The Santa Ana River eroded three channels (gaps) across the anticline thereby forming three mesas. The channels are informally referred to as the Newport, Santa Ana, and Bolsa Chica gaps". How one river, the Santa Ana River, eroded these water gap channels through the Newport/Inglewood Ridge is not made clear by the authors.

ANECDOTAL REPORTS

There are historical anecdotal reports that the Santa Ana River did shift into the head of the Newport Water Gap Channel some time during the 1800s (Fig. 6) and was then forced back into its own channel where it is now contained behind a dike barrier.

THE EFFECT OF THE WISCONSINAN SEA-LEVEL LOWSTAND

It is probable that due to the low stand of sea-level during the Wisconsinan glacial age, the Santa Ana River would have entrenched its channel down into its flood plain all the way up stream to its water gap channel in Santa Ana Canyon (Fig. 3). That being the case, the Santa Ana River could not have moved laterally to the north or to south on the inland side the Newport/Inglewood Ridge because the height of the walls of the channel it entrenched in its flood plain inland from the ridge would have prevented such a lateral move. If by chance the river made such a lateral shift, however, it would still have been confronted by the height of the Newport/Inglewood Ridge which lay between it and the coast (Fig. 7 and 8).

As sea-level rose during the transition from the Wisconsinan glacial age to Holocene time, the antecedent rivers began aggrading their channels, thereby raising the level of their channel floors with respect to the adjacent coastal plain. As the channel floors approached the level of the surrounding Orange/Los Angeles Coastal Plain, the likelihood increased that one or more of the antecedent rivers inland from their water gap channels could break out and shift laterally on the adjacent flood plain. The most likely way such a river could have made it to the shore after such a lateral shift would be if it had entered the already existing water gap channel of an adjacent antecedent river (Fig. 6).

Therefore, in Holocene time, the Santa Ana River could easily have shifted laterally into either the already formed Bolsa Chica Water Gap Channel or Newport River Water Gap Channel and flowed out to sea along with the waters of either river (Fig. 6). Unless the Bolsa Chica and the Newport Water Gap channels already existed, however, there is no way the Santa Ana River could have shifted laterally out of its own well-established water gap channel and cut a second water gap channel through the Newport/Inglewood Ridge at Newport. That is because the height of the Newport/Inglewood Ridge would have blocked its path (Fig. 7 and 8).

THE SEAWARD SHIFT OF THE WISCONSINAN SHORELINE

The Sangamon sea-level was 100 ft higher than present day level and the Wisconsinan sea-level was 300 ft below the present day level, and thus, the Wisconsinan low stand of the sea amounted to a change of 400 ft below the level of the Sangamon sea. Moreover, the drop in sea-level during the Wisconsinan Ice Age shifted (Fig. 1) the coastline miles seaward of its Sangamon location. This caused the rivers and streams that flowed to the coast to have to extend the lower ends of their courses miles seaward and lower on the shelf to reach the new Wisconsinan shoreline. The Los Angeles and San Gabriel rivers had to extend their courses up to 14 miles seaward on the San Pedro Bay shelf to reach the new shoreline. Along the northern Orange County coast, where the shelf is narrower, the Bolsa Chica, Santa Ana and Newport rivers probably extended their lower courses no more than 2 miles seaward. The mouths of all of these rivers also were 400 ft lower than their Sangamon positions and 300 ft lower than the mouths of these rivers are today.

THE LANDWARD SHIFT OF THE WISCONSINAN SHORELINE

As the Wisconsinan glacial climate waned (Fig. 1) and glacial melt-water discharged into the ocean causing sea-level to rise again. The sea advanced inland once more up to 14 miles in San Pedro Bay and at least 2 miles inland along the Orange County coast with an additional 2 miles inland where sea water entered the deeply entrenched water gap channels and at Anaheim Bay. The invasion of the water gap channels by the sea initially created deep-water estuaries along the coast of the Orange/Los Angeles Coastal Plain. Subsequently, the rivers that flowed into the heads of the water gap channels filled them with terrigenous sediment to present day sea-level. These sediment-filled estuarine channels are what we see today along the Orange/Los Angeles coast (Colburn, 2003).

As sea-level stabilized at its present-day position wave erosion attacked the coast, creating coastline retreat. This erosion process destroyed nearly one third of the seaward ends of the water gap channels of the Newport, Santa Ana, and Bolsa Chica Rivers. The effect of this episode of erosion is also marked along the coast of the Orange/Los Angeles Coastal Plain by a prominent sea cliff that ranges in height from 25 to 100 ft and a broad wave-cut bench.

During the waning phase of the Wisconsinan Ice Age and the beginning of the Holocene Epoch, or approximately 11,000 years ago, the rainfall decreased substantially, causing the antecedent rivers to shrink in flow volume to the point where they became small ephemeral streams once more with greatly reduced erosive power. Clearly these small streams appear to be underfit for the size of the water gap channels through which the streams flow today.

SUMMARY OF WATER GAP CHANNEL DIMENSIONS

1. Los Angeles River Water Gap Channel: the height of south wall (Bixby Knolls) ranges from 70 -110 ft; the height of north wall (Dominguez Hills) ranges from 175 – 195 ft; the wall to wall width of the channel is 1.5 miles; the elevation of the channel floor midway in the channel is 35 ft above sea-level; the mouth of the water gap channel is approximately 3 miles inland from the coast; the head of the water gap channel is 4.75 miles inland from the coast; the length of the water gap channel walls is approximately 1.75 miles; the elevation of the Orange/Los Angeles Coastal Plain inland from the head of the water gap channel averages 55 ft above sea-level; the depth of the water gap channel during the Wisconsinan Ice Age sea-level lowstand is estimated to have been near 300 ft below the top of the channel walls or near 200 ft below present-day sea-level.

2. The Compton River: The river flows in from the north to join the Los Angeles River midway through its water gap channel.

3. Signal Hill ridge: This ridge is part of the Newport/Inglewood Ridge that lies between the Los Angeles and San Gabriel rivers; the highest point on this ridge is Signal Hill at 350 ft + above sea-level.

4. The Los Cerritos River: This river once flowed across the Newport/Inglewood Ridge just north of Signal Hill. The rapid tectonic upwarping of the Signal Hill section of the Newport/Inglewood Ridge diverted the river from its prehistoric water gap channel, leaving behind a deeply incised notch in the crest of the ridge with a drainage divide in the middle. By definition this abandoned channel within the drainage divide is a wind gap. The diversion sent the Los Cerritos River south into the head of the San Gabriel River Water Gap Channel. The Los Cerritos River now flows to the coast along north side the San Gabriel River.

   The elevation of the drainage divide in the Los Cerritos wind gap channel is 70 ft above sea-level; Orange/ Los Angeles flood plain inland from Los Cerritos wind gap is at 45 ft above sea-level; elevation of the Long Beach flood plain on the ocean side of the wind gap is 20 ft above sea-level; the height of both walls that form the wind gap at the drainage divide is approximately 50 ft; the wall to wall width of the wind gap at the drainage divide is 2,000 ft. The length of the wind gap channel walls is approximately 1.2 miles.

5. San Gabriel River Water Gap Channel: The height of south wall at Landing Hill is 50 – 70 ft and that of the north wall at Cal State Long Beach mesa is 75 ft; the elevation of the channel floor midway up the channel is 7 ft above sea-level; the wall to wall width of the channel is 1.9 miles; the south side of the water gap channel at Landing Hill is approximately 2,000 ft from the present shoreline; the north side of the mouth of this water gap channel is located right at the present shoreline; the head of the channel is 3.5 miles inland from the coast on its north side and 1.1 miles inland from the coast at Landing Hill on its south side; the elevation of the Orange/Los Angeles Coastal Plain inland from the head of the water gap channel ranges between 10 and 15 ft above sea-level; the depth of the water gap channel during the Wisconsinan Ice Age low stand of the sea is estimated to have been close to 275 ft from the top of the adjacent channel walls or over 200 ft below present-day sea-level. The length of the north wall of the water gap channel is approximately 3.5 miles and that of the south wall is approximately 1.1 miles.

6. Anaheim Bay: This is a topographic and structural depression in the Newport/Inglewood Ridge located between Landing Hill on the north and the Bolsa Chica mesa on the south. It is an estuary in that it receives tidal water as well as rain runoff from inland; however, it does not appear that it was formed by an antecedent river. There are no observable channel walls that mark its boundaries nor is there any other surficial evidence that this channel was ever occupied by an antecedent river.

   This depression in the NIR at this location may have formed as a consequence of such a minimal degree of tectonic upwarping along the trace of the Newport/Inglewood fault zone that it produced little topographic expression.

7. Bolsa Chica Water Gap Channel: The height of south wall 35 to 55 ft; the height of north wall is 25 to 50 ft; the elevation of the floor of the channel at the midway point is 5 ft above sea-level; the wall to wall width of the channel is 1.7 miles; the elevation of the Orange/Los Angeles Coastal Plain inland from the head of the water gap channel ranges from 10 to 15 ft above sea-level; the depth of the water gap channel during the Wisconsinan Ice Age low stand of the sea is estimated to have been approximately 250 ft below the top of the adjacent channel walls or approximately 200 ft below present sea-level; approximately one third of the seaward end of this water gap channel was removed by wave erosion as the level of the sea rose during the close of the Wisconsinan Ice Age. Waves also cut into the side of the Newport/Inglewood Ridge elsewhere along the coast leaving a sea cliff facing the ocean. That part of the water gap channel that remains, measured from the coast, is approximately 2 miles.

8. Santa Ana River water gap channel: The height of the south wall is 75 – 100 ft; the height of the north wall is up to 50 ft; the floor of the channel is at 8 ft above sea-level in the center of the channel; at this location the wall to wall width of the channel is 2 ¼ miles; the elevation of the Orange/Los Angeles Coastal Plain on the inland side of the water gap channel ranges between 8 and 25 and 30 ft above sea-level; approximately one third of the seaward end of this water gap channel was removed by wave erosion leaving the remaining channel with a length of approximately 3.5 miles. Waves also cut into the seaward side of the Newport/Inglewood Ridge elsewhere along this stretch of coast leaving a sea cliff facing the ocean; the depth of the channel during the Wisconsinan Ice Age se-level lowstand is estimated to have been approximately 250 ft below the top of the channel walls or approximately 200 ft below present-day sea-level.

9. Newport River Water Gap Channel: The height of the south wall is 100 – 110 ft; the height of the north wall is 100 ft; the wall to wall width of the channel ranges from 0.4 to 0.6 miles; the elevation of the floor of the channel floor near its middle is approximately 5 ft above sea-level; the elevation of the Orange/Los Angeles Coastal Plain inland from the head of the water gap channel is 35 ft above sea-level; approximately half of the ocean-facing end of the water gap channel has been removed by wave erosion leaving a sea cliff facing the ocean; the depth of the Wisconsinan Age water gap channel estimated from the top of the channel walls is approximately 250 ft or approximately 150 ft below present-day sea-level. The length of the walls of the Newport River water gap channel is approximately the same length as that of the Santa Ana River or 3.5 miles.

   *Note that the Wisconsinan Ice Age rivers on the Orange/Los Angeles Coastal Plain were both perennial and antecedent in nature and had a flow volume and velocity more like the rivers we see today flowing to the coast in the Pacific Northwest.

THE REMNANTS OF THE RIDGE

The remnants of the Newport/Inglewood Ridge on the southern part of the Orange/Los Angeles Coastal Plain are present in the form of the elevated ground at Dominguez Hills and Signal Hill, and at the mesas at Long Beach/Bixby Knolls, Landing Hill/Seal Beach, Bolsa Chica, Huntington Beach, Costa Mesa/Newport Beach, and Newport Beach/Corona Del Mar. Each of these features is separated from its neighbors by a water gap channel except for those bordering Anaheim Bay (Fig. 3).

SUMMARY AND CONCLUSIONS

Climate changes and local tectonic upwarping interacted strongly during the late Pleistocene Epoch to produce significant changes in the landscape of the Orange/Los Angeles Coastal Plain.

Geologic and geomorphic analysis indicates that, at least as early as Sangamon time, there were six rivers crossing the Orange/Los Angeles Coastal Plain to the sea. These rivers were small ephemeral streams due to the Sangamon arid climate. The rivers, from north to south were the Los Angeles, Los Cerritos, San Gabriel, Bolsa Chica, Santa Ana, and the Newport. The linear area along the trace of the Newport/Inglewood fault zone commenced upwarping during the transition from Sangamon to Wisconsinan time, creating a ridge, herein named the Newport/Inglewood Ridge, which transected the courses of the six rivers. At that time the rivers began entrenching their individual water gap channels into the rising Newport/Inglewood Ridge and thereby avoided being blocked and/or diverted by the growing height of the ridge.

The erosive power of these rivers was enhanced by the change to the glaciopluvial climate of Wisconsinan Ice Age, during which time rainfall in Southern California increased four or five fold above today's level. The erosive power of the rivers was also enhanced by the Ice Age drop in sea-level (base level) of 300 ft below its present-day level. This powerful erosive capability made it possible for the rivers to cut their channels down through the ridge that was rising beneath their courses.

Five of the six rivers were successful in maintaining their courses without being diverted. The Los Cerritos River was unsuccessful in completing its water gap channel in the ridge at a location just north of Signal Hill. Apparently this was due to the local high rate of tectonic upwarping at that locality. Consequently, the Los Cerritos River was diverted to the San Gabriel River Water Gap Channel where it exited to the sea along with the San Gabriel River. The abandoned channel of the Los Cerritos River on the Newport/Inglewood Ridge is herein named the Los Cerritos Wind Gap.

Some references have been made in the recent geologic literature on geomorphic features of the Orange/Los Angeles Coastal Plain to the effect that a single river, the Santa Ana River, wandered over the plain cutting several different water gap channels through the Newport/Inglewood Ridge. It has been asserted that the huge water gap channels at Bolsa Chica, Upper Newport Bay and between Huntington Beach and Costa Mesa were all cut by one river, the Santa Ana River. Unfortunately, the geologic reasoning that was needed to support these assertions was not included in the articles.

The upwarping of the Newport/Inglewood Ridge and the entrenching of the water gap channels by the five remaining antecedent rivers had to be going on simultaneously from Dominguez Hills to the San Joaquin Hills. If that were not the case then one or more of these rivers that might have tried to cross over the Newport/Inglewood fault zone to get to the coast after the Newport/Inglewood Ridge had formed would have been blocked by the ridge. The ridge would have forced such a river to be diverted to one of the existing water gap channels in order to get through to the coast. This is just what happened to the Los Cerritos River that had to enter the San Gabriel River Water Gap Channel and head out to the coast after it was diverted from the Signal Hill area. As of this date, there has been no credible geological scenario proposed to support the assertion that the Santa Ana River left its course inland from its own water gap channel and moved laterally, during middle Pleistocene time, to cut a second water gap channel through the Newport/Inglewood Ridge.

There are anecdotal reports that the Santa Ana River overflowed its banks during a flood in the late l800s and entered the head of the Newport River Water Gap Channel and temporarily flowed out to the coast with the Newport River. Because of the entrenching activity these rivers undertook during the lowered base level of the Wisconsinan Ice Age, the rivers became confined to their entrenched channels at least until the latter part of the Holocene Epoch. Once their channels became aggraded with terrigenous sediment late in the Holocene Epoch, it is conceivable that one or more of the antecedent rivers could have wandered out of its own flood plain channel and moved laterally to enter the water gap channel of an adjacent antecedent river. However, it is curious (and maybe fortuitous) that all of these rivers then got back in their own water gap channels where we see them today.

All of the streams flowing through the water gap channels today seem underfit, considering the large size of these channels. The streams that flow through these water gap channels today are ephemeral, puny and vestigial remnants of their former Wisconsinan flow. The fact is that these large channels were not cut by rivers under present-day climate and base level conditions. These large channels are artifacts of the Wisconsinan Age pluvioglacial climate in which extensive amounts of rain runoff and the accompanying low stand of sea-level caused these rivers to entrench their channels in the Newport/Inglewood Ridge that was rising beneath their paths.

The geologic/geomorphologic evidence seems to support the proposition that each antecedent river on the Orange/Los Angeles Coastal Plain entrenched one and only one water gap channel in the Newport/Inglewood Ridge that was rising tectonically beneath its course.

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