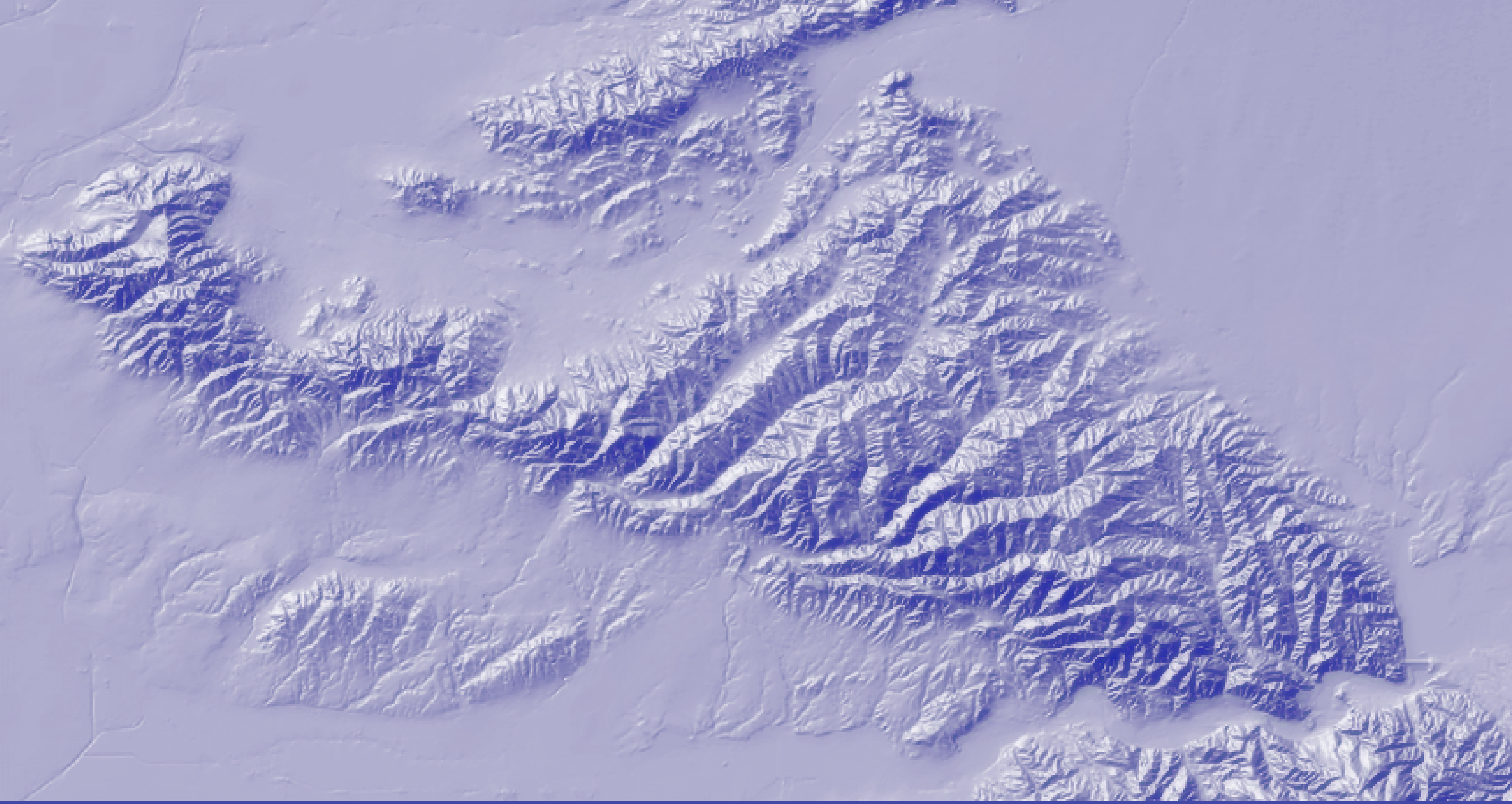

FROM ROCK, WIND, & WATER:

A
NATURAL HISTORY
OF THE
PUENTE HILLS

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Photo: USGS National Elevation Dataset (SDDS). Cover Design: Tomomi Ishihara.

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LIST OF ABBREVIATIONS

Ma	Million years ago: indicates a specific time interval, event, or date.
My	Millions of years ago: indicates a non-specific time interval.
Ka	Thousand years ago: indicates a specific time interval, event, or date.
Ky	Thousands of years ago: indicates a non-specific time interval.
Km	Kilometer.
M	Meter.

LIST OF ILLUSTRATIONS

FROM ROCK, WIND, AND WATER

INTRODUCTION

Overhead the sun courses, time passes, and on those rare clear days in Southern California when the wind and rain have washed the sky clean, what appears on the southwestern horizon from the upper reaches of Claremont, California, is a line of low slung hills that characterizes the geographical basin and range topography of the greater Los Angeles region.

The basins are, from west to east, the Santa Barbara Channel, the Ventura Basin, the San Fernando Valley, the Los Angeles Central Basin (including the coastal plains), the San Gabriel Basin, the San Bernardino/Chino Basin, collectively called the Upper Santa Ana River Basin. The Los Angeles, San Gabriel, and Chino Basins are transitional between the east-west tending Transverse and the west northwest tending Peninsular Ranges that form the northern and southern geographical borders of the greater Los Angeles region (see Figure 1).[1] The eastern Los Angeles Basin features two ranges of low hills (100-500m) that “loosely connect” the western Transverse Range and the northern Peninsular Range: the San Jose and Puente Hills.[2] The Puente Hills, which extend west northwest from the Santa Ana Mountains, may be sub-divided into three segments: the western Puente Hills (also known as the Whittier Hills), the Puente Hills, and the Chino Hills (see Figure 2). These three segments form one continuous geographical unit and are referred to as the greater Puente Hills, and they have, like all of Southern California and the greater Los Angeles area, a rich natural history.[3]

This natural history, however, usually only comes to us in the form of a simple line map on the inside of a book, corresponding not to the natural history itself and its geologic, climatological, and ecological boundaries but to human defined political boundaries. This results in the natural history of a place, like the Puente Hills, being understood as a given, for "history begins when people come on the scene." Often, our short view of time causes us to lose sight of the role that Earth's geology, climate, and ecology have on our history; they are not simply a given nor a backdrop but are an active part of the history of a place. The natural forces of geology, climate, and ecology are a part of the history of the Puente Hills.[4]

This natural history of the Puente Hills is a dynamic one, always in motion, always undergoing transformation. The Hills were formed from rock thrown up in tectonic collisions, which were continually worn down through the corrosive action of wind and water. Then the vestiges became rounded and deeply eroded hills, mantled with rock outcrops, soil, sagebrush, chaparral, oak, conifers, and grass, occasionally beset by and regenerated from fire. They were trod upon by the mastodon, mammoth, bison, dire wolf, saber-tooth cat, *Teratornis*, and blow-fly. This natural assemblage reflects the rich natural history of the Puente Hills. A story of rock and water and what comes from rock and water—erosion, soil, flora, fire, and fauna; each molding the other, this is the natural history of the Puente Hills.

OF ROCK:

INTRODUCTION: GEOLOGY

Overhead the sun coursed, time passed slowly but surely and underneath, tectonic plates floated on molten rock, bumping and grinding against each other, trying to fit but always failing. "Where two pieces rubbed edges, the earth twisted, folded, buckled over," slipped up and down, and sheared sideways violently. That happened here for millions of

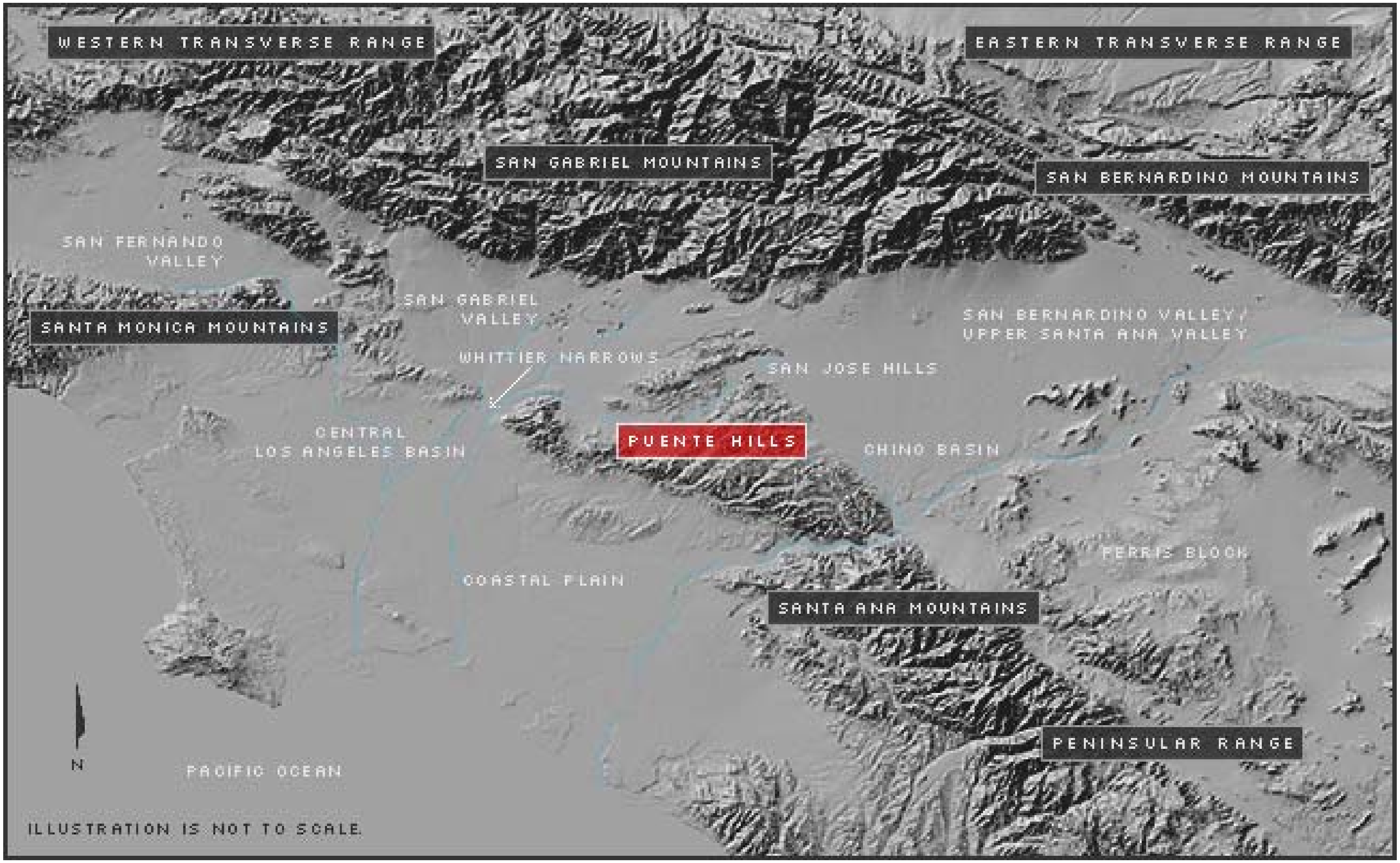

Figure 1: Greater Los Angeles Basins and Ranges.(Image courtesy of the United State Department of the Interior, Geological Survey, National Elevation Dataset, Seamless Data Distribution System, United States Data: http://seamless.usgs.gov/. Modified by author.)

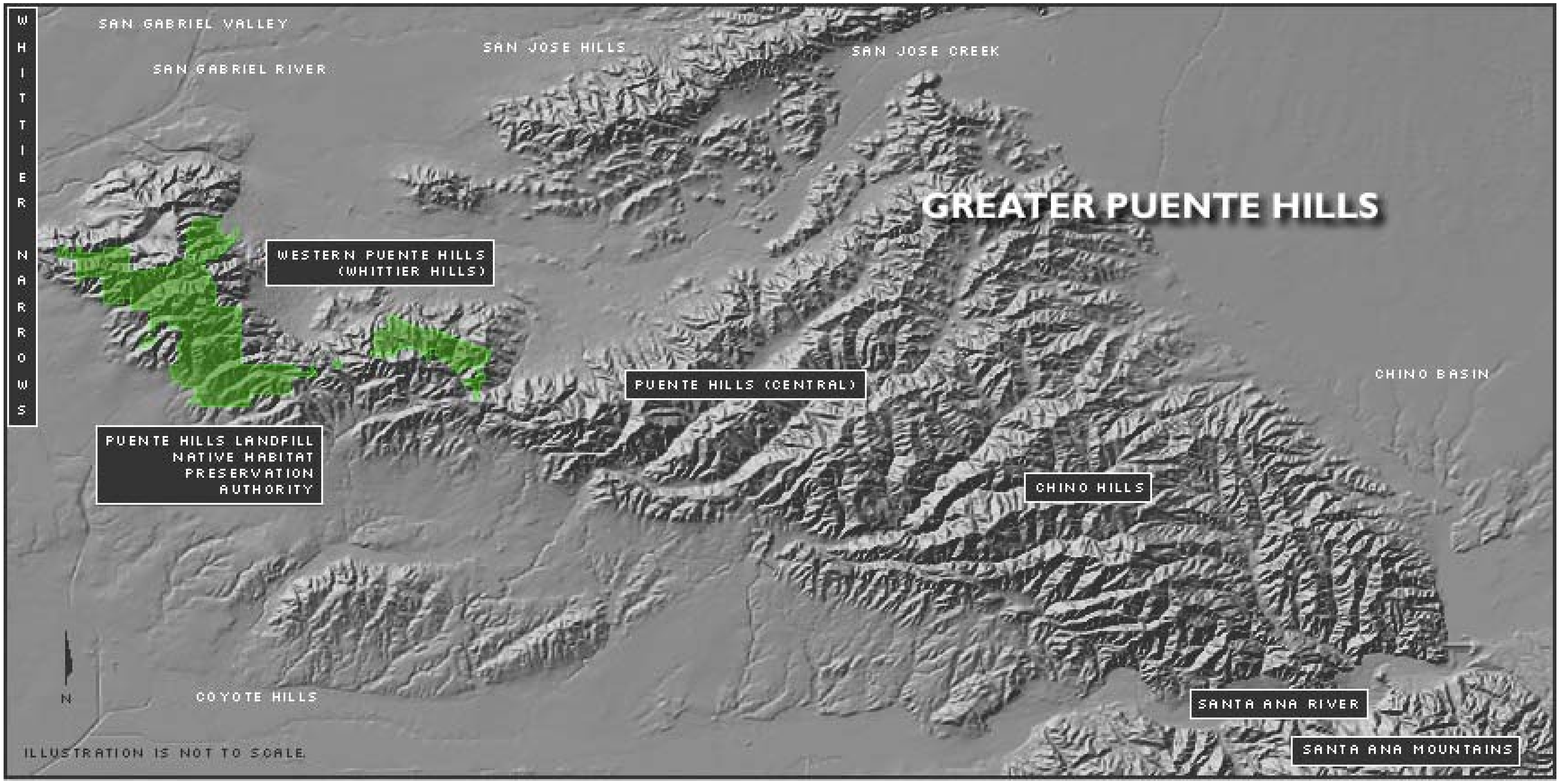

Figure 2: Greater Puente Hills. (Image courtesy of the United State Department of the Interior, Geological Survey, National Elevation Dataset, Seamless Data Distribution System, United States Data: http://seamless.usgs.gov/. Modified by author.)

years, and underneath the Hills reared up, while wind and rain cut them down, washing the dirt into the surrounding ocean. Eventually, this landscape came to look like what we know today, a wedge shaped mass of low, domed, gently rolling uplands, dissected by steep, deeply eroded canyons. The rocks of the Puente Hills can reveal something about the geologic history of the Puente Hills.[5]

PLATE TECTONICS OVERVIEW

The absence of rocks indicates that for most of their natural history, the Puente Hills, the greater Los Angeles region and Southern California existed somewhere far off the west coast of the ancestral continent of North America, called Laurentia. Had one stood on the tallest peak in an ancient mountain chain located in eastern Nevada, one would have looked out over the open ocean. There would have been nothing of the greater Puente Hills, just the ocean, slowly taking on a greater and greater load of sediment sluiced off the continent and into the ocean deep. This coastline—running roughly from the Mojave Desert through eastern Nevada into northern Utah—was a tranquil and stable place. This tranquility and stability remained for much of the long history of the western North American continent. All things geological come to an end sooner or later however, and around 245 million years ago, during the Mesozoic era, the western margin of the North American continent underwent a series of significant tectonic upheavals as two different ocean plates collided with the ancestral continent of North America.[6]

Today, geologists have divided the Earth into about twenty crustal segments called plates. These plates are thin, rigid pieces of crust that are always in motion, floating on the heat currents of the inner Earth.[7] Like bumper cars they bump and grind against each other, and when they collide, new chunks of crust and mountains are created. When an oceanic plate collides with a continental plate at a perpendicular angle, the denser oceanic crust will slide under the lighter continental land mass. As an oceanic plate plunges below the continental land mass, creating a trench, some of the oceanic plate melts becoming lighter and rises to the surface—"white-hot and violent"[8]—creating volcanoes; or, when the molten rock is cooled below the surface, it forms thick, massive deposits of granite called batholiths. Often this sequence of events—volcanism on and below the surface—is coupled with another crust forming event. As an oceanic plate plunges below the continental mass, sheets of oceanic crust are shaved off; they become compressed up against the continental landmass and sometimes can be thrust up, over, and onto the continent itself. This process is called subduction and was a major component in the formation of Southern California. Evidence of all three of these subduction events—volcanoes, granite batholiths, and the crustal shavings—are found buried deep beneath the Puente Hills.[9]

Another type of oceanic and continental plate collision results in creating a large fault as an oceanic plate approaches another plate, where both share the same direction of travel. Geologists call this a transform convergence. These two plates will grind and slip, often violently, against each other. Sometimes at the site of these parallel plate convergences, one of the plates will shear off a chunk of the other plate's crust and carry this newly acquired landmass with it. The rocks that underlie the Puente Hills reveal what occurred when two massive oceanic plates collided with the western margin of the ancient North American continent. The rock record helps separate these very complicated collisions into three distinct events; the Farallon subduction, rotation of the Transverse

Range blocks and the opening of the Los Angeles basin, and the uplift of the Puente Hills.[10]

FIRST ROCKS AND FARALLON

The first event recorded in the rock of the Puente Hills began in the Mesozoic Era, some 245 million years ago (Ma). These rocks were formed when an oceanic plate called the Farallon began to slide underneath the North American Plate (see figure 3). Volcanoes erupted on the continental margin, and oceanic sediments were compressed up against and thrust onto the continent, adding chunks of crust to the North American continental margin. This rock, compressed, wedged, and thrust onto the continent was recorded in the depths of the Puente Hills and Santa Ana Mountains as the Bedford Canyon Formation (160 Ma). While the Bedford Canyon Formation was deposited in the subduction trench and then compressed up against and thrust onto the continental margin, volcanoes were erupting—as recorded in the Santiago Peak Volcanics (135 Ma). Deep below the volcanoes, a thick, viscous molten rock was drawn up from the upper mantle and cooled in gigantic granite masses, creating the Southern California Batholith (ca. 120-95 Ma), which forms the backbone of Southern California. These formations are the rocks of a trench system, and they "form the basement of the area now occupied by the Whittier fold-fault system."[11] These basement rocks are in turn overlain by a series of marine and non-marine trench type rocks, known as the Williams, Ladd, Trabuco, Santiago Silverado, Sespe, and Vaqueros Formations (ca. 90 to 16 Ma). The visible parts of these volcanoes, rock layers, and batholiths have long since been eroded away, but their roots are still with us, deep underground, forming the Puente Hills bedrock. The final formations, the Sespe and Vaqueros, record the final stages in the life of the Farallon plate and its descent into the

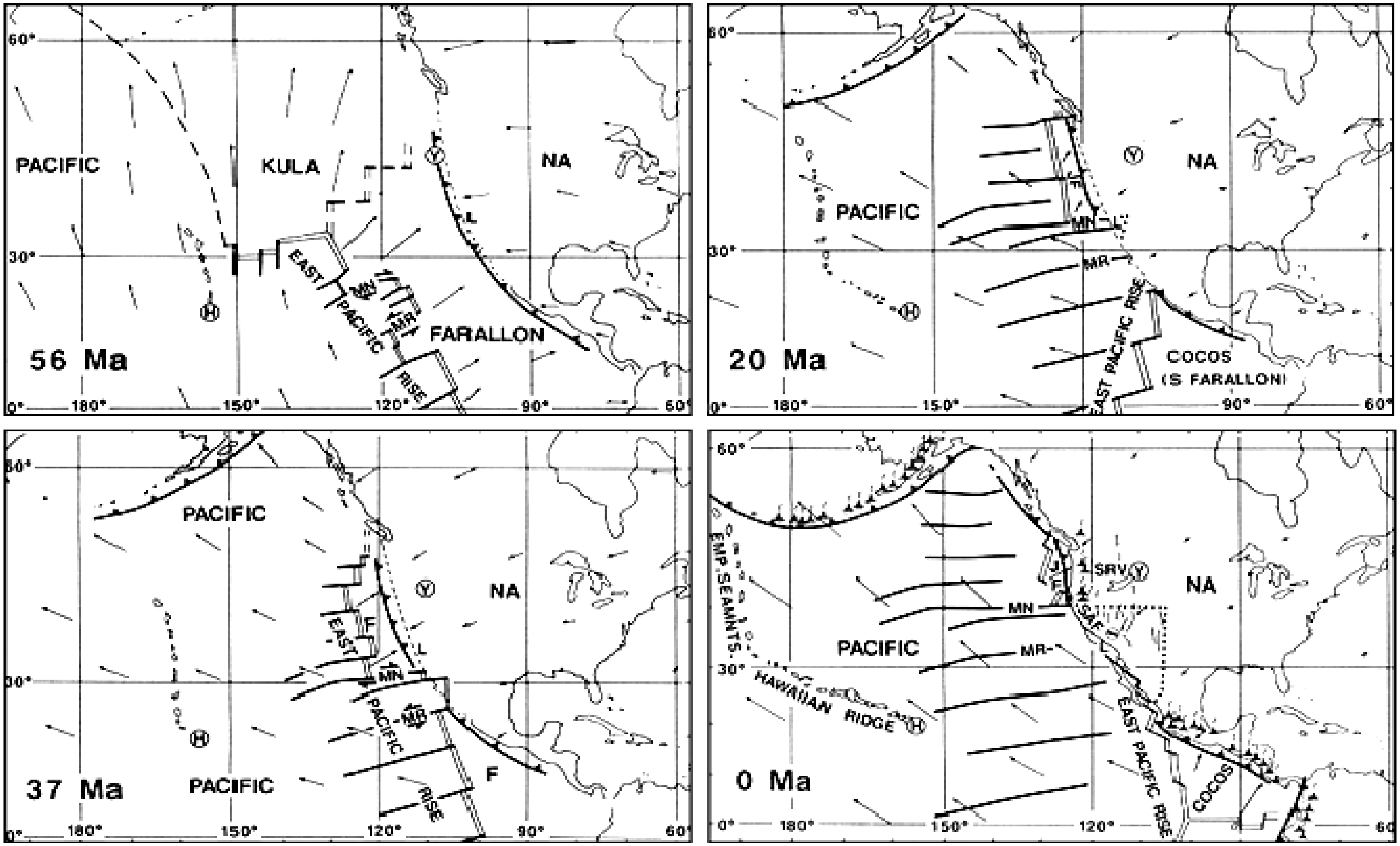

Figure 3: Farallon, Pacific, and North American Tectonic Plates. Arrows indicate relative direction of plate travel. Los Angeles (L), Farallon Plate (F), Juan de Fuca Plate (JF), Mendocino Facture Zone (MN), Murray Fracture Zone (MR), North American Plate (NA), San Andreas Fault (SAF), (Y) and (H) indicate Yellowstone and Hawaiian Hotspots. Dotted lines on 20 and 0 Ma maps indicate where the transition from subduction to transform tectonics occurs. (Illustration courtesy T.L. Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," K.T. Biddle, ed., *Active Margin Basins*, American Association of Petroleum Geologist Memoir 52 (Tulsa: The American Association of Petroleum Geologists, 1991), 44.)

mantle below the North American Plate. These rocks mark the end of one story of tectonic upheaval and hint at the beginning of a new one (see figure 11, appendix a). The rocks of the Puente Hills of this new era have a different story to tell.[12]

SECOND ROCKS AND ROTATION

The second event recorded in the rocks of the Puente Hills began some 23 million years ago. The trench system, which had for so long dominated the formation of Southern California, ended around 28 Ma, when the Pacific Plate transform convergence replaced the Farallon Plate trench system. As the "trailing edge of the Farallon Plate entered the subduction zone,"[13] the Pacific Plate was brought into contact with the North American Plate. The Pacific Plate's collision, in contrast to the Farallon Plate, which had collided with the North American plate almost perpendicularly, was "nearly parallel"[14] to the North American Plate. This new transform fault—the "notorious San Andreas Fault of California"[15]—would live up to its name; it would transform the greater Los Angeles region and give rise to the greater Puente Hills. This story is recorded in the thick marine rocks that underlie the Hills and in the volcanic rocks that form the boundary between the old plate subduction system and the new plate transform system. When the Pacific Plate slid in behind the remnants of the Farallon Plate, it made contact with the North American Plate, broke off slivers and blocks of continental crust, and began dragging them away toward the northwest. Thus, as the Pacific Plate moved almost parallel to the North American plate boundary, it picked up and began to drag Southern California and the greater Los Angeles region to the northwest.[16]

The first result of this northwesterly transfer and subsequent dragging of chunks of crust caused the Western Transverse Range[17] to break away from the Peninsular Range.

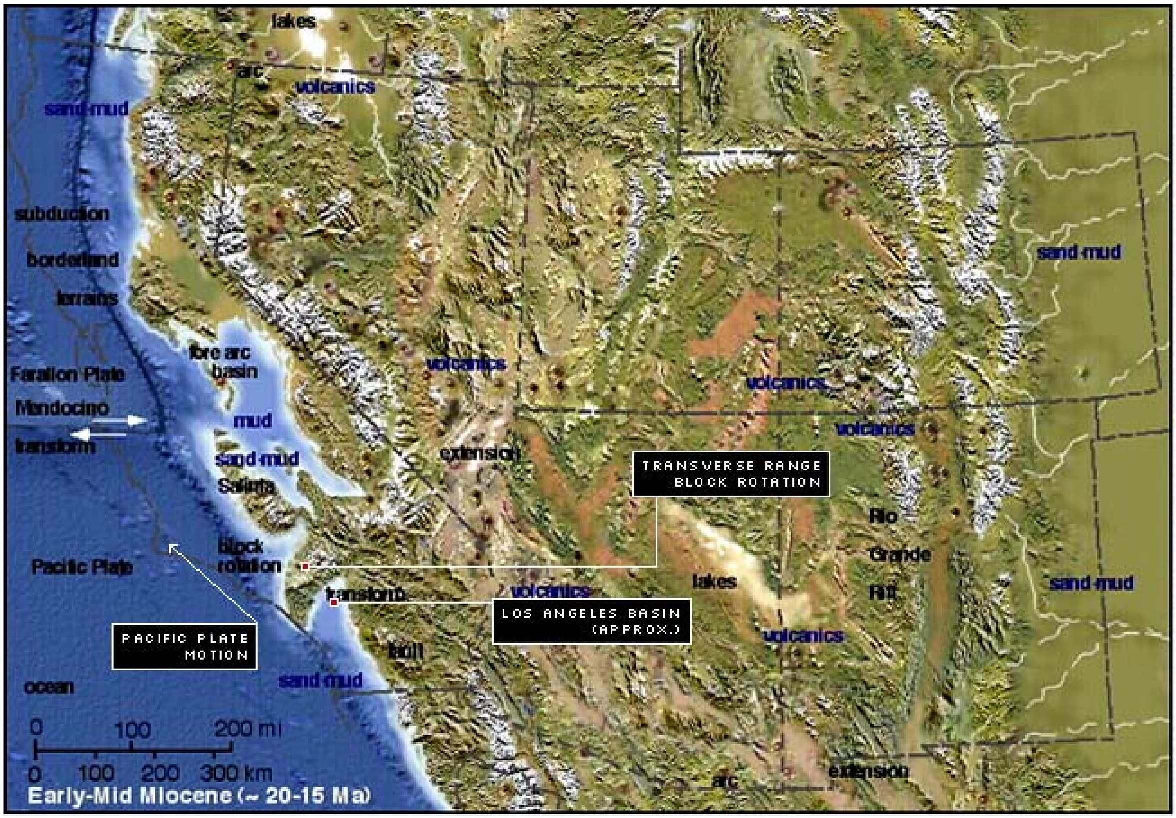

Figure 4a: Transverse Range Block Rotation, early to mid-Miocene (~20 – 15 Ma). Illustration depicting the clockwise rotation of crustal block as the Pacific Plate impacted the North American Plate, forming the Transverse Ranges and opening the Los Angeles Basin. (Illustration courtesy of Ronard C. Blakey, "Paleogeographic Evolution of the Passive-Margin to Active-Margin Transition, Tertiary Paleogeography, Southwestern US." http://jan.ucc.nau.edu/ ~rcb7/terpaleo.html.)

At one time the Western Transverse Range had lain parallel to the Peninsular Range with its southern rim, the Channel Islands, lying near San Diego. When the blocks and chunks of crust forming the bedrock of Southern California were transferred from the North American Plate, the Pacific Plate picked up the Transverse Range blocks. In effect, the Pacific Plate, scraping against the North American Plate, violently wrenched the Western Transverse Range from its position next to the Peninsular Range along the continent, rotating it clockwise 110 degrees to its present east to west configuration (see Figure 4a and 4b).[18] This block rotation stretched, thereby thinning, the remaining crust, drawing lava and the lower basement rock up to fill the gap. This process of rotating is known

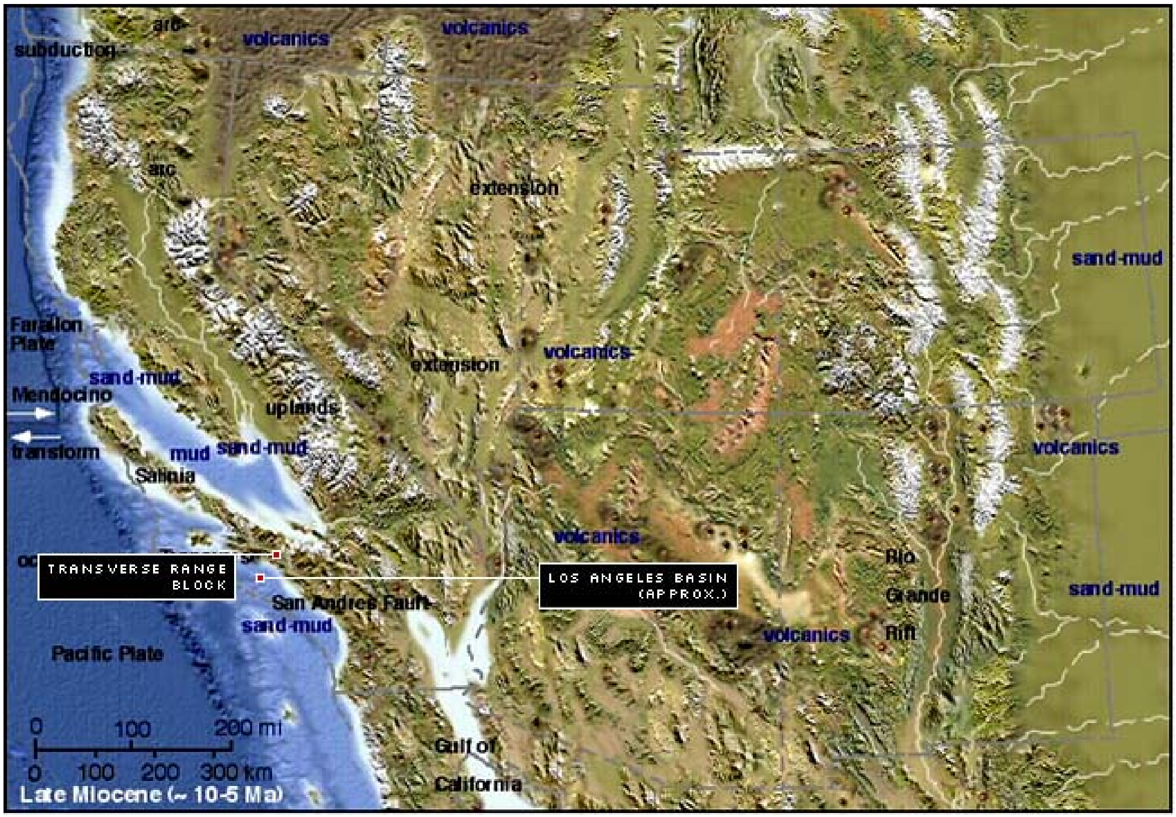

Figure 4b: Transverse Range Block Rotation, mid to late Miocene (~15 – 5 Ma). (Illustration courtesy of Ronard C. Blakey, “Paleogeographic Evolution of the Passive-Margin to Active-Margin Transition, Tertiary Paleogeography, Southwestern US.” http://jan.ucc.nau.edu/ ~rcb7/terpaleo.html.)

through the volcanic rocks—the Glendora and El Modeno volcanic rocks—which spewed out of the cracks that had opened in the bedrock of the newly-opened marine basin (see figure 11, appendix a). These formations were directly laid over the bedrock formations; their story is one of rifting, rafting, and rotation, which would ultimately result in the opening of the Los Angeles Basin and the formation of the thick marine sediments that constitute the roof rock of the Puente Hills.[19]

THIRD ROCKS AND UPLIFT

The third event recorded in the rock of the Puente Hills is the laying down of thick rock layers, which were subsequently uplifted. For over 10 million years in the marine basin opened by the rotation of the Transverse Ranges, the Los Angeles Basin and the

Figure 5a: Photograph of the Whittier Fault (toward southeast). The Miocene and Pliocene rocks labeled in the photo are the thick sedimentary rock layers laid down between ~13 and 2.5 Ma that form the roof rock of the Puente Hills. (Original Photo by J.S. Shelton and R.C. Frampton, in Bennie W. Troxel, “Geologic Guide No. 3, Los Angeles Basin,” In *Geology of Southern California*, Richard H. Jahns, ed., California Division of Mines Bulletin 170 (San Francisco: Department of Natural Resources, 1954), 28.)

nascent Puente Hills accumulated thick layers of sedimentary rock. The most important of these layers is the Puente Formation, named after the Puente Hills where these sedimentary deposits are thickest.[20] These rock layers are thick units of sandstone and siltstone and are easily seen in outcrops throughout the greater Puente Hills. This marine basin had varying water depths throughout the years with the deepest being about 6,000 feet around four million years ago. The rock that forms these layers was washed and drained off the highlands and mountains surrounding the marine basin. In this marine basin lived creatures, small and large, from whales, squid, and sharks to mollusks, oysters, microscopic floating plants called diatoms, and tiny single-celled organisms called foraminifera. When they died, their carcasses sank to the sea floor, and the rock, being washed in, overlaid these organic remains. This alternating process continued until roughly 27,000 feet of rock was accumulated (see figure 11, appendix a). The weight of these layers combined with the Earth's heat rising from below stewed this rock and organic material together for some 8 to 10 million of years, creating the sedimentary rock layers and trapping within those layers: oil—"black gold." The nature of the subsequent uplift of the Hills is revealed in the buckled, cracked, and folded nature of the rock.[21]

The uplift of the Puente Hills is the result of the Pacific Plate and its parallel movement to the northwest along the North American Plate, which began to squeeze the Los Angeles region and its thick marine sediments between the Transverse and Peninsular Ranges. The Pacific Plate caused this big squeeze as it dragged its newly acquired chunks of crust along the transform boundary formed between it and the North American Plate. This forced the Peninsular and Transverse Range blocks up against the deep granite roots of the Sierra Nevada Mountains. The intervening basinal regions between the Transverse and Peninsular Ranges were squeezed together as though in a vise. This compression took place along the joints—"zones of crustal weakness"[22] the most significant being the San Andreas Fault and the recently discovered Puente Hills Blind Thrust Fault[23]—formed in the plate collisions over the past 240 My between the various chunks of rock that underlay the Puente Hills.[24]

The most important of these joints in the Puente Hills was the Whittier fold and fault thrust system which runs their entire length on the southern side of the Hills (see figure 5a and 5b).[25] Thrust faults result from the movement of one block of rocks being pushed up and over another. Generally, fold and thrust faults are the result of compression.

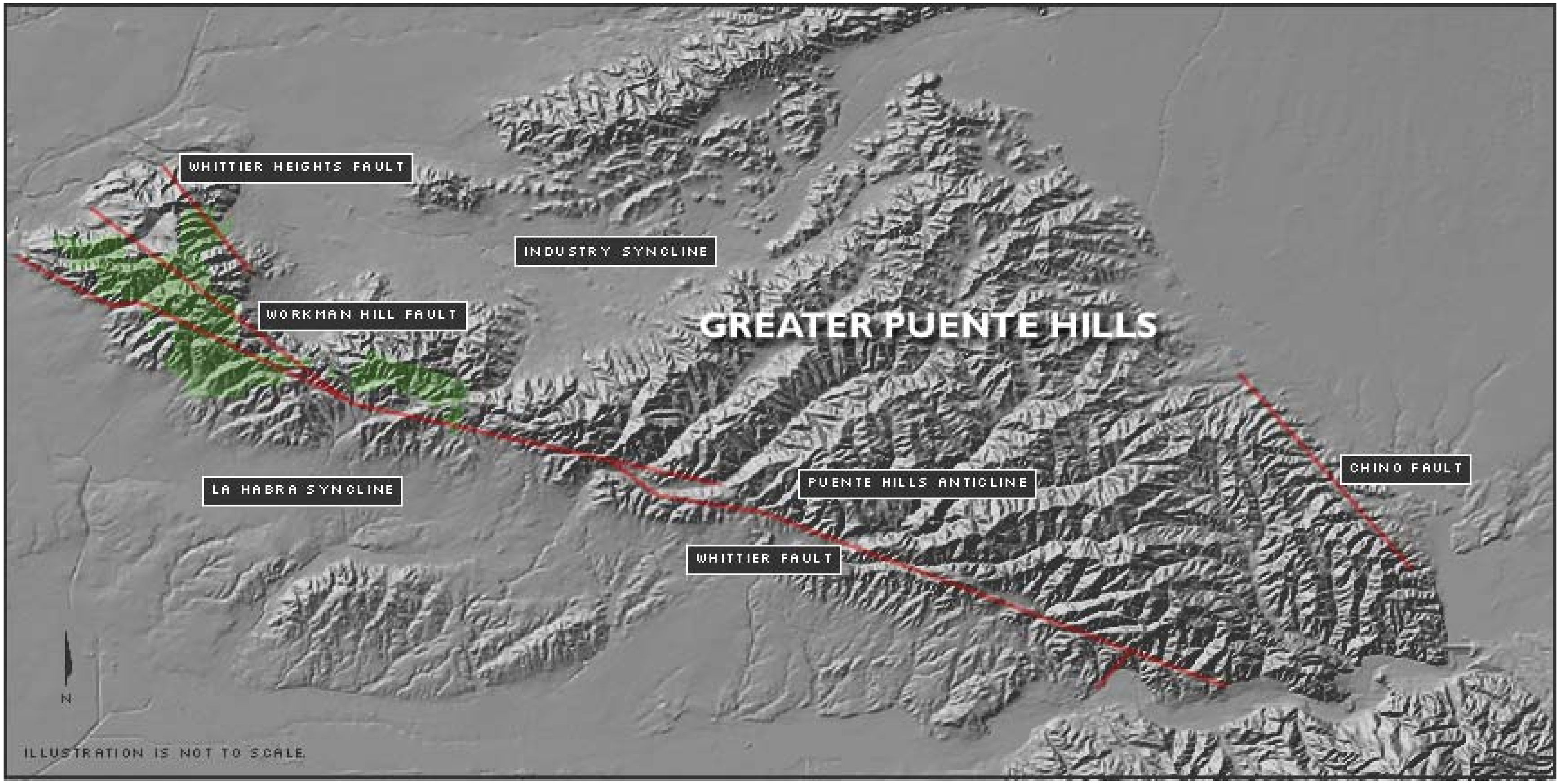

Figure 5b: Whittier Fault (overhead). (Image courtesy of the United State Department of the Interior, Geological Survey, National Elevation Dataset, Seamless Data Distribution System, United States Data: http://seamless.usgs.gov/. Modified by author.)

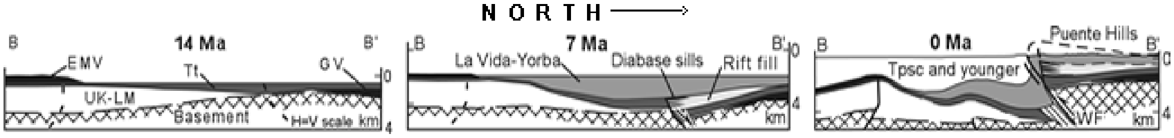

Figure 6: Puente Hills Uplift (cross-section). This cross-section figure illustrates the fold and thrust uplift of the Puente Hills due to the compression of the Los Angeles basin between the Transverse and Peninsular Range blocks. Restorations: at 14 Ma, 7 Ma, and 0 Ma. Rock formation and members: El Modeno Volcanics (Emv), Glendora volcanics (Gv), Sycamore Canyon (Tpsc), Topanga (Tt), Whittier Fault (WF), Upper Cretaceous-Lower Miocene (UK-LM) The diabase sills indicated in the figure are volcanic rocks intermixed with the Topanga formation sandstone during the rifting and rotation of the Transverse Range blocks. (Illustration by T. Bjorklund, et. al. “Miocene Rifting in the Los Angeles Basin: Evidence from the Puente Hills half-graben, volcanic rocks, and P-wave tomography,” *Geology*. 27(7), July 1999: 453).

In the case of the Puente Hills this movement and compression forced the rock material on the south side of the greater Puente Hills under the material on the north side, folding the bedrock and sediment of the northern side upward—not unlike an errant foot kicking up a rug (see figure 6). Not only were the Hills uplifted but this uplift also allowed oil to migrate through pores and cracks in the buckled rock, to collect in traps within the folded rock of the Hills (see figure 11, appendix a). Where the rock layers were broken by faulting or breached by erosion, the oil escaped to the surface forming oil and tar seeps. These events, these deeply folded and faulted rocks and Hills, are the results of two massive plates colliding.[26]

CONCLUSION: GEOLOGY

The underlying rock of the Puente Hills from the Bedford and Southern California Batholith basement to the Miocene and Pliocene sandstone, siltstones, and shale tells us a story about the natural history of the Puente Hills, about how they were made and how they came to be Hills. This was not a short process. Time passed slowly but surely for millions of years, tectonic plates floated on molten rock, bumping and grinding against each other. Where two pieces rubbed edges, the earth twisted, slipped, folded, and buckled over and up. The land was, for the most part, covered by an ocean. Water creatures lived in forests of seaweed, and when the creatures and the forests died, their bodies settled to the bottom. When mixed with sand and mud, and heated and pressurized, they became the thick layers of rock and oil underlying the Hills. This happened for 245 million years, and some hundreds of thousands of years ago, the Puente Hills emerged from the ocean, as it followed one of its many ebbs and flows, slowly becoming dry land.[27]

As the Hills emerged from their oceanic existence, wind and water immediately began to shape them. The soft sedimentary rock underlying the Hills would ultimately combine with the climatic effects of wind and rain and the surface streams and creeks, resulting in the deep erosion evident in the Hills today. Ultimately, the rock and water would combine, creating the landscape natural history of the Puente Hills. Wind and rain and streams carry their own stories of the natural history of the Puente Hills.

OF WIND AND WATER:

INTRODUCTION: CLIMATE AND EROSION

Overhead the sun coursed, and the Hills emerged to feel the bite of wind and the downpour of rain, washing them back into the surrounding ocean from which they had emerged. The Santa Ana and San Gabriel Rivers, older than the Hills, cut through the emerging Hills, leaving behind gaps. This happened here for millions of years, molding the Puente Hills into a wedge-shaped mass of low, domed, gently rolling hills dissected by steep, deeply eroded canyons and ravines. As the Puente Hills reared up and as the ocean began to retreat, the Hills began to feel the effects of climate. If the physical presence of the Hills is a visible manifestation of rock, then climate is a “less visible entity, and requires time for its full expression," but it is a "vital factor in the interpretation of the natural domain."[28] The effects of wind and water—of climate—can reveal more of the natural history of the Puente Hills.[29]

CLIMATE: MEDITERRANEAN

During the time when the ocean was receding from the interior portions of Los Angeles, the climate of Southern California was coming under the sway of a new climatic situation. The North American Continent during the Pliocene (ca. 5.3-1.8 Ma) was subjected to one of the periodic cycles of significant cooling, brought on by the development of massive ice sheets over most of the northern portion of the Northern Hemisphere. This Ice Age was intensifying and producing lower temperatures and altering wind and precipitation patterns as the Puente Hills were rising from their marine existence. This climate of 60,000 years ago (Ka) was cooler and moderately wetter, but it was for all intents and purposes similar to the modern climatic period.[30] A variety of fossil and pollen profiles indicate that the greater Los Angeles region "was not drastically different from the present," and had a "climate similar to coastal Monterey or San Francisco, California."[31] In particular, pollen and the remains of flora indicate that the greater Los Angeles region experienced a relatively cooler climate with slightly higher humidity levels, lower temperatures and elevated levels of precipitation. The mean annual temperature averaged roughly 41/51º F (modern ~ 60º F), and annual precipitation averaged 18 to 22 inches (modern ~ 15 inches) per year during the period from 60 to 14 Ka. The early years of the greater Puente Hills, then, experienced a modified Mediterranean climate with an "enhanced summer monsoon and slightly enhanced coastal winter precipitation,"[32] which was due to the continental ice sheets forcing the jet stream flow further south during the last glacial period in comparison to the modern climate of Southern California.[33]

With the end of the last glacial cycle around 10,000 years ago and the initiation of the current inter-glacial cycle, the climate of the greater Puente Hills experienced an increase in temperature, a decrease in humidity, and lower levels of precipitation. As the "oceans became progressively colder, convectional summer showers along the coastward slopes" were reduced and as "thermal contrasts increased, the Pacific high pressure system gradually strengthened and became more stable in summer."[34] This resulted in the gradual blocking of cyclonic disturbances from the north and tropical storms from penetrating up the coast from Central America during the summer.[35] Ultimately, the long, dry summers "gradually developed over the region, with a full Mediterranean climate" appearing around the end of the Pleistocene and the beginning of the Holocene.[36] The early Holocene (10-9 Ka) "was characterized by temperature and precipitation ranges similar to those of today,"[37] and during the mid Holocene (6 Ka), conditions were only slightly warmer and drier than the present. The late Holocene (3 Ka) is almost identical to today's. The paleoclimate of the greater Puente Hills was wetter and cooler but overall its climate was not remarkably different than that of today.

EROSION: BEHEADED HILLS AND THE NARROWS

The climate of the greater Puente Hills is a major factor in its natural history as is visibly seen in its deeply incised hill sides that are the past and present remains of the interface between the soil, rain, creeks, and wind, which have created this deep hillside relief through erosion.

While the erosion from wind and water is an on-going process, during the wetter climate of the past this erosion was particularly severe: "[t]he Puente Hills appear to be a remnant of a once-extensive upland surface, greatly dissected by streams."[38] The hills are now greatly eroded and "beheaded; their canyons occupied by small misfit streams."[39] These rugged, steep, deep, narrow ravines that dissect the Puente Hills are evidence of the past natural history of water. This process of severe erosion "reached its maximum during the very late Pleistocene (ca. 20 to 10 ka) epoch," when the streams would have run all year due to the wetter climate.[40] This climate would have produced some significant floods, as stream flow in the Hills "increases rapidly in response to effective rainfall."[41] The most dramatic illustration of the effect that the geology and climate (including wind and water), had on the greater Puente Hills lies in the formation of gaps, which have been used for thousands of years by all who have called the Puente Hills and surrounding valleys home.[42]

Two types of erosion gaps exist in the greater Puente Hills. Those streams powerful enough to erode through a mountain ridge created water gaps. Streams that are not swift and deep enough to continue cutting through the hills are turned aside as the Hills rise, leaving behind small gaps. These gaps will, however, continue to undergo erosion by wind and rain, which blow and wash the rock away, widening the gap. These widened gaps are called wind gaps. The greater Puente Hills contain several of these prominent land features which one can see, on any clear day from the south or the north, indenting the crest of the Puente Hills. West of the Whittier Narrows in the Repetto Hills—geologically part of the Puente Hills—are the wind gaps at Monterey Pass Road, Atlantic Boulevard, and Garfield Avenue. East of the Whittier Narrows in the main body of the Puente Hills are the wind gaps at Turnbull Canyon, Colima Road, Hacienda Road, Harbor Boulevard, Brea-Tonner Canyon, and Carbon Canyon. The prime example of a water gap in the Puente Hills, one that speaks to the power of water as a natural force, is the Whittier Narrows.[43]

The greater Puente Hills are a significant intrusion on the greater Los Angeles landscape. When driving on the 605 freeway, many people probably do not stop to consider how "they passed through the Puente Hills without crossing over any hills."[44] Probably not, but they might when they go through the Whittier Narrows. Erosion created this water gap over millions of years. The deep-sea Puente Formation submarine fan, being fed by the proto-San Gabriel River located in the already non-marine San Gabriel Mountains and Basin to the north, began to cut its way through the Hills as they rose from the ocean floor. During the late Pleistocene, as the ocean drained from the Puente Hills, the San Gabriel River took over the task of carving a path through the Hills faster than the Hills were being uplifted. The smaller streams that had once overlain the Puente Hills were turned aside. They were not powerful enough to erode their beds faster than the Hills rose, but they contributed their flow to the San Gabriel River. Among those streams that added their power was San Jose Creek. Finally, only the San Gabriel River was left, which along with wind and annual floods, continued to cut through the Hills, forming the Whittier Narrows, separating the Repetto Hills from the main body of the Puente Hills.[45]

CONCLUSION: CLIMATE AND EROSION

These wind and water gaps illustrate how rock and water have molded the natural history of the greater Puente Hills. Time passed and the Hills rose up, only to have wind and rain erode them. Streams, creeks, and rivers cut the Hills, leaving behind ravines and wind and water gaps. The visible marks of erosion, from the steep, deep, and narrow fissured hillsides, to the huge gravel and boulder deposits, and the corrosive power needed to carve out the Whittier Narrows, attest to the power of wind and water in the greater Puente Hills. This happened for thousands of years. Through the natural history of climate, of wind and water, the Puente Hills were shaped.[46]

FROM ROCK, WIND, AND WATER:

INTRODUCTION: FLORA, FIRE, FAUNA

Overhead the sun coursed and time passed slowly but surely, and underneath, the Hills reared up, while wind and rain cut them down, washing the dirt into the surrounding ocean. Life took hold in the young soil of the Hills and grew, constrained only by the climate and fire, holding in check erosion and lending a vibrant contrast to the Hills.[47]

Geology and climate are the foundations of the natural history of a region, but a vital factor that links rock and climate to their visible manifestations on the hillsides and canyons of the Puente Hills is the soil. This soil was the interface between rock, water, and flora indigenous to the Puente Hills. Soils are a vital part of any natural environment. They are composed of rock and minerals and the water and organic material of the climate and vegetation.

The soil found in the greater Puente Hills was the weathered remains of the sandstone, siltstone, and shale buried in the Hills. They formed a thin, fragile mantle covering the hillsides, rich in nutrients and prone to erosion. Depending on depth and moisture content, the soil of the Puente Hills was a tawny to dark grayish brown. Its depth was variable depending on the slope angle, with the ridge tops and crest and steeper sides being shallow (28 inches to less than an inch), and the flatter areas and ravine bottoms being thicker—upwards of ten feet. In general, the soil of the Puente Hills was typical of the Mediterranean climate, “which often coincides with areas of active geologic and tectonic activity,”[48] resulting in the formation of relatively young soils that are subject to high rates of erosion. These young soils are expansive, which means the soil will shrink and swell with changes in moisture content, making it prone to slumping and vulnerable to rapid run-off during the winter season. Overall, the soil is dry when there is no rain and wet and slick when there is rain. This soil was also filled with minerals, amino acids, and bacteria. Blown and washed into the Hills, these nutrients and bacteria would form the fragile mantle into which the flora sunk their roots. Animals would graze and browse the vegetation and eat each other, synthesizing new nutrients, but the building blocks were the nutrients formed in the soil. The soil was, then, the medium through which rock and water connected; it eroded easily but provided the nutrient mantle in which the flora rooted.[49]

FLORA: THE BLANKET

The flora found in the greater Puente Hills is part of a regional association of flora called a floristic province, four of which are found in California: Vancoverian, Sonoran, Great Basin, and Californian. The Puente Hills is in the Californian floral province, and while small in area, it provides a great diversity of plants. This past wetter, cooler climate included this California floral province.[50]

The detailed palaeontological records preserved in the Rancho La Brea Tar Pits and elsewhere reveal that the Californian floral province of the late Pleistocene (~60 – 10 ka) was primarily composed of evergreen sclerophyll flora.[51] The valleys and rolling Hills would have had an extensive mosaic that included “mixed evergreen forest, live oak woodland savanna, piñon-juniper woodland, chaparral, and other vegetation types (see figure 7).”[52] Among the flora from this time period that one would not see in the Hills

Figure 7: "**The Los Angeles Basin 25,000 years ago**." (Illustration by Pat Ortega, courtesy of the Los Angeles Natural History Museum, in Return to the Ice Age: The La Brea Exploration Guide, Los Angeles: Page Museum Education Department, http://www.tarpits.org/education/guide/ guidesm.pdf, 6.)

today were the closed-cone pine species: Monterey Pine, Bishop Pine, and Monterey Cypress.[53] In addition, these closed-cone pine species were intermingled with the oak-laurel woodlands, which "evidently ranged into the moister interior uplands," like the Puente Hills.[54] The oak-laurel floras were dominated by evergreen coast live oak, canyon live oak, southern live oak, and MacDonald oak, laurels species like the California Bay Laurel, and other evergreens and shrubs.[55] The live oak series has been recognized in the Rancho La Brea Tar Pits by the remains of its wood, leaves, and seeds and would have been mixed with "the blue elderberry, and the western hackberry."[56] The California walnut woodlands, "similar to those of *Juglans californica* occur in the Miocene Puente Formation at Puddingstone Dam near Claremont." They would have been widespread in the foothills of the coastal interior and were associated with rich pine-oak-laurel woodlands.[57] The deeper, larger, and more protected canyons and riparian areas of the Puente Hills may have included "coast redwood, … sycamore, red cedar, and raspberry."[58] Throughout the region this floral association of dense "woodlands gave way to an open oak savanna" intermixed with low, woody, sagebrush and chaparral, interspersed with grasslands on the drier and thinner soil of the Hills and plains.[59]

The sclerophyllous shrubs that make up chaparral have "a number of structural adaptations, including relatively small, thick … leaves, [with] deep root systems that can tap water in the dry season."[60] The chaparral shrub regularly added to the understory of the "pine-oak-laurel woodland," often "confined to warmer, south facing slopes, together with oak woodland and mixed evergreen forest."[61] This shrub series included: toyon, elderberry, lemonadeberry, and scrub live oak. The coastal sage flora of the area contributed the understory of the pine-oak-laurel woodland as well. This series was "dominated by semiwoody plants with brittle stems, soft wood, and rich branching, as exemplified by species of: black, purple, white, California sage, California buckwheat, California Encelia, buckthorn, and prickly-pear cacti."[62] In addition to the scrub flora of coastal sage and chaparral, the Hills would also have contained grasslands that inter-fingered and extended into the sage, chaparral, and into pine-oak-laurel woodland.[63] The grassland series was inclined toward perennial grasses, mixed with numerous annual species. This grassland floral association included needle grasses like purple stipa (*Stipa pulchra*), feather grass (*Stipa pennata*), spear grass (*Stipa calamagrostis*), and Munz (*Aristida hamulosa*), and bunchgrasses, like Goldenstar (*Bloomeria crocea*) and Blue dicks (*Dichelostemma capitatum*).[64] Throughout the region, then, the overall flora of the greater Puente Hills, during the late Pleistocene epoch (~50 to 10 Ky), was probably comprised primarily of an evergreen sclerophyll vegetation, which was a "mixed evergreen forest, live oak woodland savanna, piñon-juniper woodland, chaparral, and other vegetation types," like grasslands, coastal sage and chaparral scrub.[65]

These floral associations all exhibited adaptations to living in the Southern California climate when it was wetter, and they successfully adapted to the emergence of a hotter and drier climate between 10 - 3 Ka.[66] When the climate switched to a modern situation, the pine-oak-laurel woodlands would have retreated to the northern and north central regions of California and up the mountain sides, like the Santa Ana Mountains where some of these species are still found, following the cooler temperatures and rainfall. The riparian woodlands would have retreated deeper into the moist canyons, and the scrub and live oak would have persisted but in a reduced acreage. The chaparral and coastal sage scrub would have advanced, filling the niches vacated by the retreating pine-oak-laurel woodlands.

Many of these floral associations persisted into the present era in the greater Puente Hills. The flora of the modern greater Puente Hills is, as it was in the past, a "mosaic of scrub, grassland, and woodland."[67] The chaparral and sage scrub are the "most widespread, particularly coastal sage scrub dominated by California Sagebrush, California Buckwheat, and Black Sage." These sage scrub species are intermixed in a shrubby sumac and oak woodland dominated by toyon, laurel sumac, lemonadeberry, coast live oak, and California black walnut. Both the "coastal sage and sumac woodland are most prevalent in the western Puente Hills."[68] The Hills still contain scattered patches of native bunchgrasses and herbaceous forbs. Much of the pre-human flora that does remain is readily visible and protected in areas like the Puente Hills Landfill Native Habitat Preservation Authority and Chino Hills State Park. One aspect of natural history, intimately tied to vegetation as well as wind, rain, and rock, is fire. Fire plays a role in regenerating this vegetation.[69]

FIRE: REGENERATION

Fire has played for thousands of years a role in the natural history of the greater Puente Hills. While fire was part of the natural environment, determining what is a representative natural—pre-human influence—fire scheme is difficult. Some aspects of fire, however, can point to what might be a natural fire condition for the region. “Under natural conditions, lightning is the only predictable source of ignition, but its importance varies.”[70] Local thunderstorms and general summer storms do occur, producing lightning; but they are for the most part “quite rare” in Southern California.[71] When fires are caused by lightning in this region, they generally exhibit irregular burning, “sometimes creeping through brush and other times raging,” which means that natural fires burn with varying intensity and severity.[72] In addition, fires can burn for months before being snuffed out by rain or natural barriers, though occasionally fires can “‘hold over’ in logs, even during rainstorms, to be reignited at a later time.”[73] Fires that burn slowly for months or that smolder in protected areas can result in large-scale fires, particularly in the low-humidity and high-foëhn—Santa Ana—wind conditions of late summer and fall. The unpredictability of fires in regions like the Puente Hills means that the oak woodlands, chaparral, and coastal sage communities could remain “fire-free for a century or more.”[74] In general, fires were part of the natural history of this region, and while they may not have been frequent, they nevertheless played a role in the floral communities of the Hills.[75]

Many floral species in the greater Los Angeles region and the Puente Hills require some fire prompts (heat, smoke, or charred wood) for regeneration and germination, particularly the chaparral and coastal sage communities. These floral communities are not necessarily adjusted to fire but to a particular fire scheme. Indeed, the chaparral floral community is very resilient to fire. Chaparral species, like buckthorn,[76] were adapted to the small-scale fire scheme, recovering quickly after a fire, "stump-sprouting"[77] from ground level in the low crowns that remained after fire. The sage scrub was also adapted to fire with a number of species re-sprouting quickly from root crowns and generally germinating only after periodic fires. Fire was also important to perennial forbs whose underground bulbs sprouted quickly in response to the addition of nutrients to the soil produced during a fire. Grasses are also adapted to fire. The bunchgrass Blue dick (*Dichelostemma capitatum*) resprouts after fire not through seeds but through cormlets. When fire clears out the overstory thereby reducing competition for sunlight, water, and nutrients, these cormlets vigorously sprout, sometimes after having lain dormant in the soil for years.[78] Cacti also were adapted to fire, with the rosette shape of yuccas protecting its "inner growth bud from destruction in all but the hottest fires."[79] Most fires, then, of a pre-human natural history were probably small, but "the bulk of the landscape burned in a few large fires that occurred at unpredictable intervals in association with autumn foëhn winds,"[80] and were an integral part of regenerating the floral community.[81]

Time passed and upon the plains and Hills, life took hold and grew, constrained and regenerated only by the climate and periodic fires, blanketed with Needlegrass and wildflower, sagebrush: purple, black, and white and the multiplicity of chaparral, from toyon to elderberry. Fire regenerated the Puente Hills. The open, rolling slopes were covered by live oak forests, the oaks protecting grassy understories and mixing with walnut and coffeeberry. The Hills were home to vast tracts of flora, and the fauna browsed and grazed the vegetation of the communities and followed trails through the wind and water gaps.[82]

FAUNA: FANTASTIC CREATURES

Overhead the sun coursed, hundreds of thousands of times, and time passed slowly but surely, and the Hills emerged, “home to fantastic creatures.” The geology and climate of a region are the foundations of that region’s natural history, and through soil, they are linked to one of its visible manifestations: flora. Flora then links to another visible manifestation of the natural history of a region: fauna. A good deal of what we know about early wildlife in the greater Los Angeles region comes from the wonderfully preserved fossils of the Rancho La Brea tar pits, which record the landlife present in this region during the period from 40 to 10 Ka.[83]

The fossil record reveals that the climate and vegetation of the greater Los Angeles region supported an incredibly diverse range of animals, including insects, amphibians, reptiles, birds, and mammals. These animals, in conjunction with the flora of the Puente Hills, formed a life cycle including herbivores, which ate the plants; carnivores, which ate other animals; and scavengers, which *finished off* the remains, replenishing the land. The herbivores, such as horses, ground sloths, camels, bison, antelope, the Columbian Mammoth, and the American mastodon ate the vegetation: bunch and needle grasses, oak leaves, blue elderberry, and sagebrushes of the plains and Hills. The American mastodon, a mammal resembling the mammoth, had unique attributes suited to living in this region (see figure 8). Standing 7 to 8 feet tall, it preferred “moist, woody habitats,” and seems to have followed an “opportunistic, mixed foraging strategy,”[84] with teeth that were blunt and conical to grind and tear the twigs and leaves so common in the area. Its tusks, made of dentine or ivory, were around 15 feet long, protruding horizontally from its upper jaw, which helped the animal reach into high or low places to break off branches. While eating

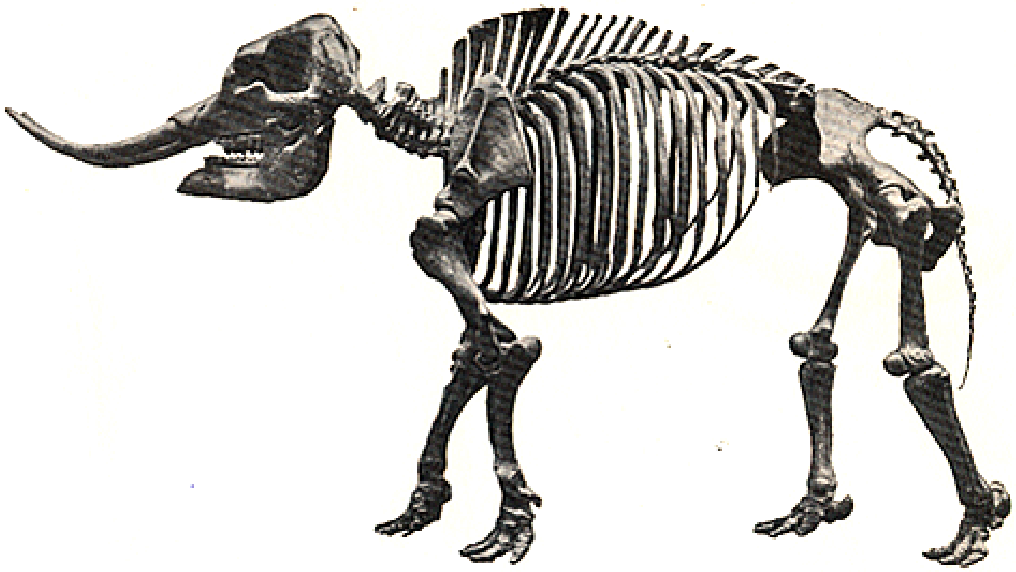

Figure 8: American Mastodon Skeleton. (Illustration courtesy of the Los Angeles Natural History Museum, in Chester Stock, *Rancho La Brea: A Record of Pleistocene Life in California*,Science series, no. 20, Paleontology, no. 11. 6th ed. (Los Angeles: Los Angeles County Museum, 1965), 49.)

the twigs and leaves of the trees and brush that interspersed the grasslands, the mastodon would also have used the vegetation for cover in evading its prime predator, the saber-tooth cat. As part of the life cycle, the herbivore, like a mastodon, would become a food source for the large predators stalking the Hills.[85]

A number of carnivores populated the Puente Hills region including the dire wolf, the short-faced bear, the grizzly bear, the American lion, and the saber-tooth cat. Just as herbivores used the vegetation for cover, so did the carnivores. The saber-tooth cat could hide in the brush and trees waiting for an unsuspecting mastodon. The saber-tooth cat was equally suited to live in the Puente Hills region (see figure 9). Its muscular build and strong bones, coupled with its camouflaging allowed the saber-tooth cat to lie in wait for its prey instead of chasing it as did other carnivores, for “these creatures were not fleet-footed carnivores like the lion or tiger.”[86] Its teeth were also well-suited for the environment as long, saber-like canines allowed the cat to penetrate the tough hides of animals like the mastodon: “In attacking a large mammal like an elephant, mastodon,

Figure 9: Saber-tooth Cat Skull (right-lateral view). (Illustration courtesy of the Los Angeles Natural History Museum, in Chester Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, Science series, no. 20, Paleontology, no. 11. 6th ed. (Los Angeles: Los Angeles County Museum, 1965), 37.)

or ground sloth, the saber-tooth cat would probably seek a vulnerable spot on the body or neck of its prey, grip the victim with its powerful front limbs and claws and repeatedly stab with the upper canines thus inflicting a jagged wound."[87] The saber-tooth cat would then eat its fill, leaving "large, edible portions of their kills behind" for other animals and for scavengers to find, which introduces another stage in the life cycle of the Puente Hills.[88]

Numerous mammalian and non-mammalian scavengers roamed the Puente Hills, such as dung beetles, blow flies, maggots, rats, foxes, coyotes, hawks, eagles, and a large condor-like creature called *Teratornis merriami* (see figure 10). A creature like the *Teratornis* would finish off the remains of dead animals like a mastodon left by a

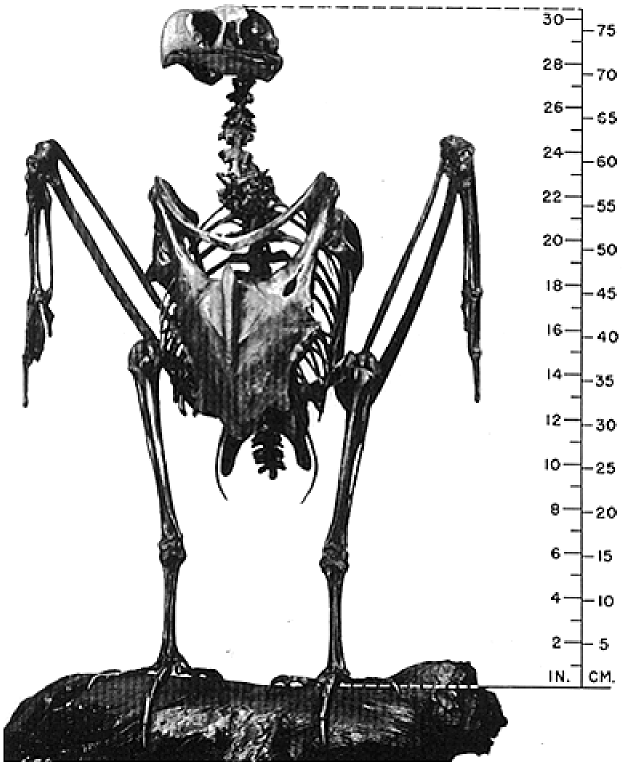

Figure 10: *Teratornis* Skeleton. (Illustration courtesy of the Los Angeles Natural History Museum, in Chester Stock, *Rancho La Brea: A Record of Pleistocene Life in California*,Science series, no. 20, Paleontology, no. 11. 6th ed. (Los Angeles: Los Angeles County Museum, 1965), 59.)

saber-tooth cat. This bird, one of the largest birds of flight, stood two and a half feet high with a wing-span of at least 12 feet and a weight of around 50 pounds. Its size alone would have scared off other scavengers, while its enormous claws and beak could rip the fleshy remnants off the remaining bones. After the *Teratornis* had its fill, minute agents of decomposition would have infiltrated the carcass, such as the blow flies and maggots. Eventually, the remains would have returned to the soil, mixed with water, which fed the plants, completing one of many cycles in the natural history of the Puente Hills. With this mix of fauna, the Puente Hills and the greater Los Angeles region must have been a wild and wooly place.[89]

CONCLUSION: FLORA, FIRE, FAUNA

Time passed slowly but surely in the Hills, and species died. It rained less and less. That happened here for thousands of years. Eventually it came to look like what we know. Trees grew: cottonwood, willow, sycamore, elderberry, toyon, and mulefat. Grass grew: perennial bunchgrasses, Needlegrass, and wildflowers. Sagebrush grew: purple, black, and white, along with buckwheat, mustard, cacti, and poison oak. Up in the hills, all these species grew. The open, rolling slopes were covered by live oak forests, the oaks protecting grassy under stories, and mixing with walnut and coffeeberry. This flora provided food, becoming part of the life cycle in the Puente Hills.[90]

The Hills were once "home to fantastic creatures." The Columbian Mammoth, over twelve feet tall at the shoulder; the American mastodon, almost that tall; giant camels and giant bison; and early horses; ground sloths eighteen feet high; tapirs; bears, lions, saber-tooth cats, dire wolves; a *Teratornis* with a twelve-foot wingspan; let us not forget the creatures of the ocean: the whale, the shark, the diatom, foraminifera, and the plankton. There were hundreds of different species of mammals living here once upon a time; and snakes, lizards, insects, spiders—all of them were here (many still remain). In the skies there were birds of every kind. Gulls, pelicans, cranes, herons, egrets, ducks, geese, swans, starlings, pheasants, partridge, quail, finches, grouse, blackbirds, roadrunners, jays, swallows, doves, larks, falcons, hawks, eagles, and condors, the biggest birds in the world. All this flora and fauna grew wildly; they were the cycle of life that filled the rolling uplands and deep canyons of the Hills. While some species—flora or fauna—are now gone, extinct or driven out, some persist to this day in the Puente Hills: the toyon, the purple and black sage, buckwheat, oak woodlands, and mulefat still exist. While the fox, mountain lion, bobcat, mule deer, and red-tailed hawk have replaced the mastodon, saber-tooth cat, and *Teratornis*. They were the first inhabitants of the Hills, and we stand on their bones, walk their trails; we stand among them.[91]

FROM ROCK, WIND, AND WATER

CONCLUSION

Overhead the sun coursed, hundreds of billions of times, and time passed slowly but surely, and underneath tectonic plates floated on molten rock, bumping and grinding against each other, trying to fit but always failing. Where two pieces rubbed edges, the earth twisted, folded, buckled over. Ocean covered the land. Water creatures lived in forests of seaweed, and when the creatures and the forests died their bodies settled to the bottom, were mixed with sand and mud, heated and pressurized, and became thick layers of rock and oil. Underneath the Hills reared up while wind and rain cut them down, washing the dirt into the surrounding ocean. Time passed slowly but surely, and it rained less and less. The Hills were crossed by rivers. They were older than the Hills, cutting through the Hills as they rose, leaving behind wind and water gaps. Upon the plains and Hills, flora took hold and grew: purple needlegrass, black sagebrush, toyon, and oak. The Hills were home to the mastodon, bison, saber-tooth cat, and *Teratornis*. There were hundreds of different species of animals living here, once upon a time—all of them were here. This warm, dry basin between the sea and sky teemed with life: flora and fauna. We would have counted them not by numbers but by the acre. They grew and died and grew again. We stand upon this natural history in the Puente Hills.[92]

This natural history is a dynamic one, always in motion, always undergoing transformation; however, we very often take this natural history as a given: "[l]ess obvious is the importance of precursor events … in creating the architecture of the surface and subsurface within which recent events are expressed." Our short view of time causes us to lose sight of the role that Earth's geology, climate, and ecology have on our history; they are not simply a given nor a backdrop but are the active subsurface of our history.[93]

When we travel the freeways and roads of the Puente Hills, we are traveling the ancient paths of wind and water, first used by the animals and later the human. The history of the Puente Hills is both human and natural; the natural forces of geology, climate, and ecology are a part of their history. These are the dynamics of the Puente Hills' history, a story of rock, wind, and water and what comes from rock, wind, and water: "[t]he geographic environment is a mould into which the human race has been poured, and the history of the race has been shaped by that mould."[94]

END NOTES

[1] Robert S. Yeats, “Tectonics of the San Gabriel basin and Surroundings, Southern California,” *GSA Bulletin*, 116(9/10), September/October 2004: 1158. The Transverse Range is divided into two sections, the eastern section includes the San Bernardino Mountains, and the western section, which includes the San Gabriel and Santa Monica Mountains. The Peninsular Range is the west northwest tending mountain range that extends from northern Baja Mexico through the San Diego region and terminates against the western Transverse Range in the eastern Los Angeles Basin, as the Santa Ana Mountains Yeats “Tectonics of the San Gabriel basin and Surroundings, Southern California,” 1158.

[2] Daniel S. Cooper, “Breeding Landbirds of a Highly Threatened Open Space: The Puente-Chino Hills, California,” *Western Birds*, 31(2000): 213 – 214.

[3] When viewed from above, the Puente Hills (see Figure 1 and Figure 2) form a wedge shape as they emerge out of the Santa Ana Mountains to the southeast and run to a point just east of downtown Los Angeles to the northwest. The Hills are bound on the southeast by the Santa Ana River, which separates the Puente Hills from the Santa Ana Mountains. The Hills are bound to the northwest by the San Gabriel and Rio Hondo Rivers at the Whittier Narrows. To the north, the Hills are bound by San Jose Creek separating the Puente Hills from the San Jose Hills (which are geologically a part of the Puente Hills, sharing a majority of their natural history with the Puente Hills, but lie outside the scope and space of this essay) and the San Gabriel Basin. The greater Puente Hills stretch for 434 square miles, totaling about 277,760 acres. To the south and the east, the Hills are bound by faults, large and small—the Whittier Fault is located to the south, and the Chino Fault is on the eastern side with numerous smaller faults located throughout the hills. One fault that is of importance to the greater Los Angeles region is the recently discovered Puente Hills Blind Thrust Fault. While this fault is named after the Puente Hills, it is located outside the Hills proper underlying the Coyote Hills to the south. This fault does not appear to be directly related to the specific geologic events that formed the Puente Hills (see endnote 23 for more information). The Puente Hills, based on their geographical and geologic position and formation, form a formidable “‘peninsula’ of open space through the urbanized eastern Los Angeles Basin.” (Cooper, “Breeding Landbirds of a Highly Threatened Open Space,” 214) Currently, only a small percentage of the greater Puente Hills is preserved as open space, concentrated in the east in the roughly 12,000 acre Chino Hills State Park and in the west in the roughly 3,800 acre Puente Hills Landfill Native Habitat Preservation Authority (the organization that commissioned this essay). These areas are preserving the last vestiges of the pre-Human—or at least pre-1700 Spanish-Anglo—natural history. The natural history that formed and took place within the Puente Hills unfolded across the entire breadth of the Puente Hills regardless of human constructed boundaries. See Yeats, “Tectonics of the San Gabriel Basin and Surroundings, Southern California,” Robert P. Sharp and Allen F. Glazner, *Geology Underfoot in Southern California*, (Missoula, Montana: Mountain Press Publishing Company, 1993), T. Bjorklund and K Burke, “Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin,” *Journal of Structural Geology*, 24(2002): 1370 – 1, Cooper, “Breeding Landbirds of a Highly Threatened Open Space: The Puente-Chino Hills, California,” *Western Birds*, 31(2000): 214, and the Puente Hills Landfill Native Habitat Preservation Authority: http://www.habitatauthority.org/whoweare.shtml, for information on square miles, acres, elevation, and geographical location. See also, United States Department of the Interior Geographical Survey, 7.5 minute topographic series revised quadrangles: “San Dimas,” “Baldwin Park,” “El Monte,” “Prado Dam,” “La Habra,” “Yorba Linda,” “Ontario,” and “Whittier,” (Washington, D.C.: Government Printing Office, 1981).

[4] Ted Steinberg, *Down to Earth: Nature’s Role in American History*, (New York: Oxford University Press, 2002), 4. The Puente Hills Landfill Native Habitat Preservation Authority commissioned this paper as part of a series of histories about the land they administer; however, the discussion of the natural history of a place cannot be done without contextualizing the natural history throughout the formation of the Puente Hills as a totality. See also, William Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature*, (New York: W.W. Norton & Company, 1996) for a good introduction to current environmental historical scholarship on the human construction of nature as a place with clearly defined borders.

[5] Kim Stanley Robinson, *The Gold Coast*, (New York: Tom Doherty Associates Book, Inc., 1988), 43 – 45.

[6] Sharp and Glazner, *Geology Underfoot in Southern California*, 5. John McPhee, *Basin and Range*, 3rd ed., (New York: Farrar, Straus & Giroux, 1981), 23. David G Howell, *Tectonics of Suspect Terranes: Mountain Building and Continental Growth,* (New York: Chapman and Hall, 1989), 180. W. Scott Baldridge, *Geology of the American Southwest: A Journey through Two Billion Years of Plate-Tectonic History,* (New York: Cambridge University Press, 2004), 154.

[7] The heat of the inner Earth is responsible for the plate motion. The iron core of the Earth is surrounded by the mantle, about 1,800 miles thick, upon which the crust rests. The crust and the upper part of the mantle is called the lithosphere, this lithosphere is what comprises these twenty or so plates. Oceanic plates are generally 3 miles thick and continental plates about 20 miles thick. Below these plates is the upper mantle rock, called the asthenosphere. The rocks of the asthenosphere are slightly radioactive and produce more heat than they lose, causing a convection current—where hot material rises and then moves to the side as it cools. The plates slide on the surface of this viscous molten rock, moving at different speeds and directions; some move less than an inch per year while others move as much as four inches per year, with the average being about two inches per year. Sharp, *Geology Underfoot in Southern California*, 2 – 3.

[8] McPhee, *Basin and Range*, 23.

[9] McPhee, *Basin and Range*, 23. Sharp, *Geology Underfoot in Sourthern California*, 2 – 3. Baldridge, *Geology of the American Southwest*, 186. Also see Don Mellor, *American Rock: Region, Rock, and Culture in American Climbing,* (Woodstock, Vermont: The Countryman Press, 2001), 48 – 63.

[10] McPhee, *Basin and Range*, 180. Baldridge, *Geology of the American Southwest*, 186.

[11] T. Bjorklund and K Burke, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," *Journal of Structural Geology,* 24(2002): 1370 – 1.

[12] Bjorklund and Burke, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," 1370 – 1. The Farallon Plate still exists as remnants in the Juan de Fuca and Cocos Plates along the Pacific Coast, and as fragments that underlie North America from the Southwest to deep (2700km) beneath the western Atlantic Ocean. Baldridge, *Geology of the American Southwest*, 216-218.

[13] Baldridge, *Geology of the American Southwest*, 215.

[14] Baldridge, *Geology of the American Southwest*, 215.

[15] Baldridge, *Geology of the American Southwest*, 216.

[16] McPhee, *Basin and Range*, 180. See Baldridge, *Geology of the American Southwest*, and T. L. Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," K.T. Biddle, ed. *Active Margin Basins*. American Association of Petroleum Geologist Memoir 52. (Tulsa: The American Association of Petroleum Geologists, 1991), 35-134.

[17] "Trending essentially east-west across the regional grain of Southern California is the Transverse Range province, which comprises elongate mountain ranges and valleys, chains of hills, an broad basins that are geologically very complex. The province as a whole resembles the adjoining Coast Range and Peninsular Range regions in several aspects, but is distinguished from them by prevailing east-west structural trends." Jahns, "Investigations and problems of southern California Geology," 17). The Transverse Ranges are separated into eastern and western segments. The eastern Transverse Ranges are, from east to west: the Eagle, Pinto, Little San Bernardino, and San Bernardino. The western Transverse Ranges are, from east to west: the San Gabriel, Santa Monica, Santa Susana, Topatopa, Pine, and Santa Ynez Mountains. Only the western Transverse Range blocks were rotated during the switch from a subduction to transform margin. The Peninsular Ranges are, from south to north: Laguna, Vallecito, Santa Rosa, Agua Tibia, San Jacinto, and Santa Ana Mountains. In addition, the Peninsular Range extends, through the Southern California Batholith formation, into the Baja Peninsula of Mexico and is geologically part of the overall Peninsular Range block system. (Richard H. Jahns, "Investigations and problems of southern California Geology," Section 1 in Chapter I, *Geology of Southern California,* Richard H. Jahns, ed., California Division of Mines Bulletin 170. (San Francisco: Department of Natural Resources, 1954), 11.

[18] The rotational axis was the San Gabriel to Chino Hills to Cristianitos faults east of the Puente basin. This fault system—though each individual member would remain active between 18 to 0 Ma—was replaced by a

series of other faults. Foremost among those beginning 6 Ma was the San Andreas Fault system. When the San Andreas became active, the Pacific Plate continued to drag the Peninsular Range block northward opening the Gulf of California as Baja California was detached from its initial position along mainland Mexico and added to the Pacific Plate. For more information on the rotation of the Transverse Range blocks. See Yeats, "Tectonics of the San Gabriel basin and Surroundings, Southern California," 1158 – 1182, Baldridge, *Geology of the American Southwest*, Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," and Raymond Ingersoll and Peter E. Rumelhart, "Three-stage Evolution of the Los Angeles Basin, Southern California," *Geology*. 27(7) July 1999.

[19] Peter W. Weigand, et. al., "The Conejo Volcanics and other Miocene Volcanic Suites in Southwestern California," in *Contributions to Crustal Evolution of the Southwestern United States*, Andrew Barth ed., Special Paper 365, (Boulder Colorado: The Geological Society of America, 2002), 197. See Ingersoll and Rumelhart, "Three-stage Evolution of the Los Angeles Basin, Southern California," 595. See also, Baldridge, *Geology of the American Southwest,* and Andrew J. Meigs and Michael E. Oskin, "Convergence, Block Rotation, and Structural Interference Across the Peninsular-Transverse Range Boundary, Eastern Santa Monica Mountains, California," in *Contributions to Crustal Evolution of the Southwestern United States,* Andrew Barth ed., Special Paper 365, (Boulder Colorado: The Geological Society of America, 2002) 279 – 295.

[20] The Puente Formation is divided into four members: the La Vida, Soquel, Yorba, and Sycamore Canyon members. Below the Puente Formation lies the Topanga Formation, which is interbedded with the El Modeno and Glendora volcanic intrusions. The Puente Formation and the Topanga formations are from the Miocene age (23.5 - 5.3 Ma). Lying above the Puente Formation are the Pliocene age (5.3 – 1.8 Ma) Fernando, San Pedro, and La Habra Formations. Bjorklund, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," 1370.

[21] Bjorklund and Burke, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," 1370/1. Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," 100 – 101. See Harold W. Hoots and Ted L. Bear, "History of Oil Exploration and Discovery in California," section 1 in chapter IX, *Geology of Southern California,* Richard H. Jahns, ed., California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954), 5 – 11. See also, Tanya Atwater, "Santa Barbara Channel Oil: Structural Evolution." University of California, Santa Barbara. http://emvc.geol.ucsb/download/sboilchannel.php. Dr. Atwater has created a series of Apple Quicktime™ animations that dramatize the events of the last 85 My and the building of Southern California, see http://emvc.geol.ucsb.edu/downloads.php.

[22] Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," 45.

[23] The Puente Hills Blind (a fault that does not breach the surface) Thrust Fault (PHT) was discovered in 1999 by John Shaw et. al., and was determined to be the cause of the 1987 Whittier Narrows M_w 5.9^+ event; and was, thus, named after the nearest major structural element in the region, the Puente Hills. The PHT "extends for more than 40km along strike in the northern Los Angeles basin from downtown Los Angeles east to Brea in northern Orange County. The fault consists of at least three distinct geometric segments, termed Los Angeles, Santa Fe Springs, and Coyote Hills, from west east." John H. Shaw, et.al, "Puente Hills Blind-Thrust System, Los Angeles, California," Bulletin of the Seismological Society of America, 92(8), December 2002: 2946. Research on this fault has determined that it is, next to the San Andreas Fault, the most significant fault structure in the greater Los Angeles and Southern California region and poses a significant earthquake threat (it is believed to be capable of generating a significant earthquake (M_w 6.0 to 7.0^+). Geologists are still investigating its structure and are undecided as to its full extent and role in the tectonic evolution to the greater Los Angeles region. The geologist Robert S. Yeats, who has studied numerous geologic aspects of the eastern Los Angeles Basin including the San Gabriel Basin (see Yeats, "Tectonics of the San Gabriel Basin and Surroundings, Southern California") and its relationship to the Puente Hills, as well as participating in studies of the Puente Hills themselves with Tom Bjorklund (see T. Bjorklund, et. al., "Miocene Rifting in the Los Angeles Basin: Evidence from the Puente Hills half-graben, Volcanic Rocks, and P-wave Tomography," *Geology,* 27(7), July 1999: 593-596), has found no evidence (yet) indicating that the PHT played a role, major or minor, in the geologic development of the Puente Hills. Dr. Yeats states, "[t]he blind thrust is generally assumed to pass beneath the San Gabriel Basin as a

décollement. If so, there does not appear to be a close correlation between the blind thrust and uplifted terrain east and west of the San Gabriel Basin. Uplift accompanying the blind thrust affects the Coyote Hills and Santa Fe Springs anticline, but not the Puente Hills, which are more likely to owe their uplift to the restraining bend in the Whittier fault. Yeats, "Tectonics of the San Gabriel Basin and Surroundings, Southern California," 1177. More research remains to be done on the extremely complex nature of the PHT and its intersection with other fault structures in the greater Los Angeles Region and what role, if any, it plays or played in the uplift of the Puente Hills. In addition, the most recent geologic study completed specifically on the greater Puente Hills by Tom Bjorklund, et. al. (see Bjorklund and Burke, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," and T. Bjorklund, et. al., "Miocene Rifting in the Los Angeles Basin: Evidence from the Puente Hills half-graben, Volcanic Rocks, and P-wave Tomography") does not mention nor credit the PHT with any significant role in the uplift of the Puente Hills but credits the uplift to the actions of the Whittier Fault system.

[24] See Ingersoll and Rumelhart, "Three-stage Evolution of the Los Angeles Basin, Southern California," see also, Baldridge, *Geology of the American Southwest.*

[25] The main structural elements of the greater Puente Hills include the Puente Hills anticline, the La Habra syncline, and the Whittier Fault system. The Whittier Fault is located along the southern edge of the greater Puente Hills and runs their entire length (40km) from their emergence north of the Santa Ana Mountains. It is a steeply dipping fault (~50-55º) that extends to a depth of two kilometers. The Whittier fault system can be divided in three structurally distinct segments, a southeastern segment, a central segment, and a northwestern segment. The central segment of the Whittier fault runs for 18km from Telegraph Canyon to La Mirada Creek and forms the southern boundary of the Puente Hills anticline. The southeastern segment runs for 9km, from Telegraph Canyon to the Santa Ana River where in the vicinity of the Santa Ana Canyon, the Santiago Peak Volcanics are exposed. The northwestern segment runs for 15km from La Mirada Creek to the Whittier narrows. The northwestern most exposure is found in the Turnbull Canyon area, where the La Vida Member is juxtaposed against the Sycamore Canyon Member of the Puente Formation. The Whittier fault has been traced north to just short of the San Gabriel River, where it breaks north, becoming the East Montebello fault. There are several smaller faults: the Workman Hill fault, Whittier Heights fault, and the Handorf fault, all three of which are located in the northwestern section of the Puente Hills. Bjorklund, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," 1371- 1385.

[26] Wright, "Structural Geology and Tectonic Evolution of the Los Angeles Basin," 45. Bjorklund and Burke, "Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin," 1383 – 1384. Mellor, *American Rock: Region, Rock, and Culture in American Climbing*, 51. See Frank S. Parker, "Origin, Migration, and Trapping of Oil in Southern California," section 2 in Chapter IX, *Geology of Southern California*, Richard H. Jahns ed., California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954), 11 – 21, and Ingersoll and Rumelhart, "Three-stage Evolution of the Los Angeles Basin, Southern California."

[27] Robinson, *The Gold Coast*, 43-45.

[28] Harry P. Bailey, "Climate, Vegetation, and Land Use in Southern California," section 2 in Chapter I, *Geology of Southern California*, Richard H. Jahns, ed., California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954), 31.

[29] Robinson, *The Gold Coast*, 43-45.

[30] Bennie W. Troxel, "Geologic Guide No. 3, Los Angeles Basin," in *Geology of Southern California*, Richard H. Jahns, ed., California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954). U.S. Department of Defense, Army Corps of Engineers. "Watershed Characteristics: Brea Canyon Watershed," Chapter IV, http://www.spl.usace.army.mil/resreg/htdocs/brea/ chap4.pdf. The modern Southern California climate is classified as Mediterranean and is, overall, semi-arid to semi-humid with warm, dry summers and cool, moist winters. The wind during much of the year is on shore. However, during the late summer and fall the wind switches from on shore to off shore. This switch is caused by the buildup of a high pressure system in the Great Basin region between the Sierra Nevada and the Rocky Mountains. http://en.wikipedia.org/wiki/Santa_ana_wind. This air mass, pulled by gravity and lower coastal air pressure, surges out of the Great Basin and into the Los Angeles basin, bringing dry conditions and is known as '*Santa*

Ana' weather. Bailey, "Climate, Vegetation, and Land Use in Southern California," 32 – 3 and Troxel 1. In the Puente Hills, the average daily minimum/maximum temperatures range from 42/66 in winter to 59/90 in summer; all-time extremes of temperature are about 22/113 (DOD, ACE, "Brea Canyon," 4-3). The mean annual precipitation is about 15 inches, of which nearly all is received during the months of December through March . Bailey, "Climate, Vegetation, and Land Use in Southern California," 31 - 32.

[31] *Return to the Ice Age: The La Brea Exploration Guide*. Los Angeles: Page Museum Education Department, http://www.tarpits.org/education/guide/guidesm.pdf, 6.

[32] E.R. Wahl, "Holocene Paleoecology of Southern California: Methods, Results, and Testing of Climate Model Simulations," abstract, http://abstracts.co.allenpress. com/pweb/esa2000/abstracts/EUG-3-41-22.html.

[33] Joan Brenner Coltrain, et. al., "Rancho La Brea Stable Isotope Biogeochemistry and its Implications for the Palaeoecology of Late Pleistocene, Coastal Southern California," *Palaeogeography, Palaeoclimatology, Palaeoecology*, 205 (2004), 200. See also, Joy K. Ward, et.al. "Carbon Starvation in Glacial Trees Recovered from the La Brea Tar Pits, Southern California," *PNAS*, 102(3), January 18, 2005: 692.

[34] Daniel I. Axelrod, "Outline History of California Vegetation," *Terrestrial Vegetation of California*, Michael G. Barbour and Jack Major, eds., Special Publication No. 9, (Sacramento: California Native Plant Society, 1988), 144.

[35] Axelrod, "Outline History of California Vegetation," 144.

[36] Axelrod, "Outline History of California Vegetation," 144.

[37] Wahl, "Holocene Paleoecology of Southern California," http://abstracts.co.allenpress. com/pweb/esa2000/abstracts/EUG-3-41-22.html. Coltrain, et. al., "Rancho La Brea," 200.

[38]"Watershed Characteristics: Brea Canyon Watershed," Chapter IV, 4-2.

[39]"Watershed Characteristics: Brea Canyon Watershed," Chapter IV, 4-2.

[40]"Watershed Characteristics: Carbon Canyon Watershed," Chapter IV, 4-1.

[41]"Watershed Characteristics: Brea Canyon Watershed," Chapter IV, 4-7.

[42] See also, U. S. Department of Defense, Army Corps of Engineers. "Watershed Characteristics: Carbon Canyon Watershed," Chapter IV. http://www.spl.usace.army.mil/resreg/htdocs/ Carbon Canyon/ Chapter4.pdf.

[43] Sharp, *Geology Underfoot in Southern California*, 79.

[44] Sharp, *Geology Underfoot in Southern California*, 77.

[45] Sharp, Geology Underfoot in Southern California, 77. See also, Richard H. Jahns, ed. Geology of Southern California, California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954).

[46] Robinson, *The Gold Coast*, 43-45.

[47] Robinson, *The Gold Coast*, 43-45.

[48] "Watershed Characteristics: Carbon Canyon Watershed," Chapter IV, 4-2.

[49] David Allan, "Soils, Weathering, and Nutrients," Global Change Program, University of Michigan, http://www.globalchange.umich.edu/globalchange1/current/lectures/soils/ soils.html, 8. Norman L.Christensen, "The Effects of Fire on Physical and Chemical Properties of Soils in Mediterranean-Climate Shrublands," *The Role of Fire in Mediterranean-Type Ecosystems*, José Moreno and Walter C. Oechel, eds, Ecological Studies 107, (New York: Springer-Verlag, 1994), 81 – 83. Ken Killham, *Soil Ecology* (New York: Cambridge University Press, 1994), 2 – 3. The official base taxonomic classification for the soils of the Puente Hills is: Calcic and Pachic Haploxerolls and Typic Argixerolls of the Mollisols series (U.S. Department of Agriculture, Forest Service, "Subsection M262Bf: Santa Ana Mountains," *Ecological Subregions of California*, (USDA, Natural Resources Conservation Service, USDI, Bureau of Land Management), http://www.fs.fed.us/r5/projects/ecoregions/m262bf.htm). See also, G.J. Retallack, *Soils of the Past: An Introduction to Paleopedology*, (Boston: Unwind Hyman, 1990), U.S. Department of Agriculture, Natural Resources Conservation Service, *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys*, Agricultural Handbook 436, 2nd ed., (Washington, D.C.: Government Printing

Office, 1999), and U.S. Department of Agriculture, Natural Resources Conservation Service, *Keys to Soil Taxonomy*, 10th ed., (Washington, D.C.: Government Printing Office, 2006).

[50] Information obtained from the entrance sign to the Rancho Santa Ana Botanic Garden, Claremont, California.

[51] Sclerophyllous vegetation has hard leaves that allow the vegetation to resist semi-dry to dry conditions typical of Mediterranean climates with cool, moist winters and hot, dry summers. http://en.wikipedia.org/wiki/Sclerophyllous.

[52] Axelrod, "Outline History of California Vegetation," 157. Coltrain, "Rancho La Brea Stable Isotope Biogeochemistry and its Implications for the Palaeoecology of Late Pleistocene, Coastal Southern California," 200.

[53] Daniel I. Axelrod and Fran Govean, "An Early Pleistocene Closed-Pine Forest at Costa Mesa, Southern California," *International Journal of Plant Sciences*, 157(3), May 1996: 327. These closed-cone pine species are now found only in limited numbers in the region surrounding Monterey, California.

[54] Axelrod, "Outline History of California Vegetation," 162.

[55] Axelrod, "Outline History of California Vegetation," 162. "Oak-laurel forest characterizes several undescribed … floras at sites in coastal southern (Puente, Modelo, Topanga floras) and central California (Carmel flora). Situated west of the San Andreas Fault, they have been displaced northwest approximately 180 miles (290 km) since the late Miocene (13 My)," indicating a climate well removed from frost. Axelrod, "Outline History of California Vegetation," 162. The laurels included "*Nectandra*, *Ocotea*, *Persea*, *Umbellularia*;" the other evergreens included "*Annona*, *Arbutus*, *Ficus*, *Ilex*, *Lyonothamnus*, *Pistacia*, and *Sabal*, and sclerophyllous shrubs, notably *Cercocarpus*, *Laurocerasus*, *Quercus*, and *Rhu.s* Axelrod, "Outline History of California Vegetation," 162."

[56] Chester Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, Science series, no. 20, Paleontology, no. 11, 6th ed., (Los Angeles: Los Angeles County Museum, 1965), 68.

[57] Axelrod, "Outline History of California Vegetation," 167. The rich oak-palm-laurel forest included "*Persea*, *Quercus* (*virginiana*, *potosiana*), and *Sabal*, as well as *Cercocarpus*, *Karwinskia*, *Lyonothamnus*, and *Quercus* (*terbinella*), which contributed to the understory. Axelrod, "Outline History of California Vegetation," 167."

[58] *Return to the Ice Age: The La Brea Exploration Guide*, 7.

[59] Axelrod, "Outline History of California Vegetation," 164 – 165.

[60] Axelrod, "Outline History of California Vegetation," 175.

[61] Axelrod, "Outline History of California Vegetation," 177, 175. See also, Maurice Carlton Price, "Geology of the Southeastern Puente Hills," (Masters thesis, Claremont Graduate School, 1953), 5.

[62] Axelrod, "Outline History of California Vegetation," 178. Sage is exemplified by species of: "*Artemisia*, *Baccharis*, *Encelia*, *Ericamerica*, *Eridictyon*, *Eriogonum*, *Hazardia*, *Helianthemum*, and *Salvia*". Axelrod, "Outline History of California Vegetation," 178. Prickly-pear cactus patches became common as the climate became hotter and dryer, and "are usually found on the sandstone and conglomerate, but also may be found on shale or even very fine sandstone." Price, "Geology of the Southeastern Puente Hills," 5.

[63] Harold F. Heady, "Valley Grassland," *Terrestrial Vegetation of California*, Michael G. Barbour and Jack Major, eds., Special Publication No. 9, (Sacramento: California Native Plant Society, 1988), 494.

[64] Heady, "Valley Grassland," 495.

[65] Axelrod, "Outline History of California Vegetation," 157.

[66] The floral associations that persisted, in spite of the climatic change to hotter, drier summers, were "preadapted structurally to live under [a] Mediterranean climate," having developed the ability to shift their germination into the earlier, moister part of the year as they experienced a progressively longer period of summer drought between 50 to 3 Ka. Axelrod, "Outline History of California Vegetation," 144 – 145, 157, 158.

[67] Cooper, "Breeding Landbirds of the Puente-Chino Hills," 216.

[68] Cooper, "Breeding Landbirds of the Puente-Chino Hills," 216.

[69] World Wildlife Fund, *California coastal sage and chaparral (NA1201)*, (WildFinder: Online database) http://www.worldwildlife.org/wildworld/profiles/ terrestrial/na/na1201_full.html. Price, "Geology of the Southeastern Puente Hills," 4 – 5. Forest Service, "Subsection M262Bf: Santa Ana Mountains." *Ecological Subregions of California*. See also, Bailey, "Climate, Vegetation, and Land Use in Southern California," "Chaparral," http://en.wikipedia.org/wiki/Chaparral, Tom Chester, "Vascular Plants of the Whittier Hills, Los Angeles County," http://www.tchester.org/plants/floras/pr/whittier_hills_print.html, and Bob Muns, "Flora of the Skyline Trail, Puente Hills, Los Angeles County," http://www.tchester.org/plants/muns/pr/ skyline_trail.html.

[70] Jon E. Keeley, "Historic Fire Regime in Southern California Shrublands," *Conservation Biology*, 15(6), December 2001: 1542.

[71] Jon E. Keeley, "Native American Impacts on Fire Regimes of the California Coastal Ranges," *Journal of Biogeography*, 29: 303.

[72] Keeley, *Conservation Biology*, 1543.

[73] Keeley, *Conservation Biology*, 1544.

[74] Keeley, *Conservation Biology*, 1544.

[75] There is a controversy within the fire and wild-land management system, with one side claiming that the natural condition for Southern California fire regimes was "one of frequent, small fires that fragmented the landscape" into a fine-grained mosaic of vegetation age classes that "precluded large, catastrophic fires." This side feels that natural fire regime has been lost in Southern California due to highly effective fire suppression method via humans." Keeley, *Conservation Biology*, 1537. They propose "that if fire managers could 'restore' a natural fire regime of frequent, small fires through prescription burning, they could eliminate the hazard of catastrophic fires in Southern California." Keeley, *Conservation Biology*, 1537. The other side has shown, however, that the supposed natural fire regime was anything but *natural*. It was rather the product of intensive use of fire as tool for managing the floral community by indigenous people and later by the Spanish and Mexican colonizers. See Keeley, *Conservation Biology*, Keeley, *Journal of Biogeography*, Jon E. Keeley, et. al, "Fire Suppression Impacts on Postfire Recovery of Sierra Nevada Chaparral Shurblands," *International Journal of Wildland Fire*, 14(2005): 255-265, and Kat M. Anderson, *Tending the Wild: Native American Knowledge and the Management of California's Natural Resources*, (Berkeley: University of California Press, 2005) for more information on this controversy and indigenous uses of fire in managing the floral landscape of Southern California.

[76] *Ceanothus* (spp.) is a genus consisting of 50 to 60 species of shrubs or small trees in the buckthorn family (*Rhamnaceae*), like Holly-Leaf Red Berry (*Rhamnaceae ilicifolia*), which are found in the Whittier Hills at present. http://en.wikipedia.org/wiki/Ceanothus.

[77] Axelrod, "Outline History of California Vegetation," 175.

[78] "Dichelostemma capitatum," http://en.wikipedia.org/wiki/Dichelostemma_capitatum.

[79] Woodward, "Mediterranean Shurblands," http://www.runet.edu/~swoodwar/CLASSES/GEOG235/ biomes/medit /medit.html.

[80] Keeley, *Conservation Biology*, 1542.

[81] Keeley, *Conservation Biology*, 1542 – 1544. Keeley, *Journal of Biogeography*, 303. Woodward, "Mediterranean Shrublands." The chaparral floral community is incredibly diverse and each floral type responds to the fire regime differently based on: season, frequency, intensity, and severity of the burn. See, Christensen, "The Effects of Fire on Physical and Chemical Properties of Soils in Mediterranean-Climate Shrublands," 79-95, José Moreno and Walter C. Oechel, "Fire Intensity as a Determinant Factor of Postfire Plant Recovery in Southern California Chaparral," *The Role of Fire in Mediterranean-Type Ecosystems*, José Moreno and Walter C. Oechel, eds., Ecological Studies 160, (New York: Springer-Verlag, 1994), 26-45. See also, World Wildlife Fund, "California Coastal Sage and Chaparral (NA1201)," www.worldwildlife.org /wildworld/profiles/terrestrial/na/na1201_full.html, The California Chaparral Field Institute, "Fire and People," www.californiachaparral.com/firepeople.html, and "Chaparral," en.wikipedia.org/wiki/Chaparral. See also, Ronald D. Quinn, "Animals, Fire, and Vertebrate Herbivory in Californian Chaparral and Other Mediterranean-Type Ecosystems," *The Role of Fire in Mediterranean-Type Ecosystems*, José Moreno and

Walter C. Oechel, eds, Ecological Studies 160, (New York: Springer-Verlag, 1994), 46-78, for information on the relationship between animals and fire.

[82] Robinson, *The Gold Coast*, 43-45.

[83] Robinson, *The Gold Coast*, 43-45.

[84] Coltrain, "Rancho La Brea Stable Isotope Biogeochemistry and its Implications for the Palaeoecology of Late Pleistocene, Coastal Southern California," 202.

[85] Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, 49 – 50. Donald E. Savage, "Cenozoic Land Life of Southern California," section 6 in Chapter III, *Geology of Southern California*, Richard H. Jahns, ed. California Division of Mines Bulletin 170, (San Francisco: Department of Natural Resources, 1954), 56 – 57. *Return to the Ice Age: The La Brea Exploration Guide*, 11.

[86] Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, 36.

[87] Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, 36. Of curious note, "the backward position of the nasal opening presumably permitted the animal to breathe with head plunged deeply into the side of its victim, and the presence of a strongly corrugated gum covering the ridges of the hard palate may have rendered service in blood-sucking." Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, 37.

[88] Coltrain, "Rancho La Brea Stable Isotope Biogeochemistry and its Implications for the Palaeoecology of Late Pleistocene, Coastal Southern California," 201. *Return to the Ice Age: The La Brea Exploration Guide*, 19.

[89] Stock, *Rancho La Brea: A Record of Pleistocene Life in California*, 57 – 58. *Return to the Ice Age: The La Brea Exploration Guide*, 9.

[90] Robinson, *The Gold Coast*, 43-45.

[91] Robinson, *The Gold Coast*, 43-45.

[92] Robinson, *The Gold Coast*, 43-45.

[93] Ingersoll and Rumelhart, "Three-stage Evolution of the Los Angeles Basin, Southern California," 593 Steinberg, *Down to Earth*, 4.

[94] A. E., Perkins, Draper Museum of Natural History, Buffalo Bill Historical Center.

Appendix A: Puente Hills Stratigraphic/Event Column

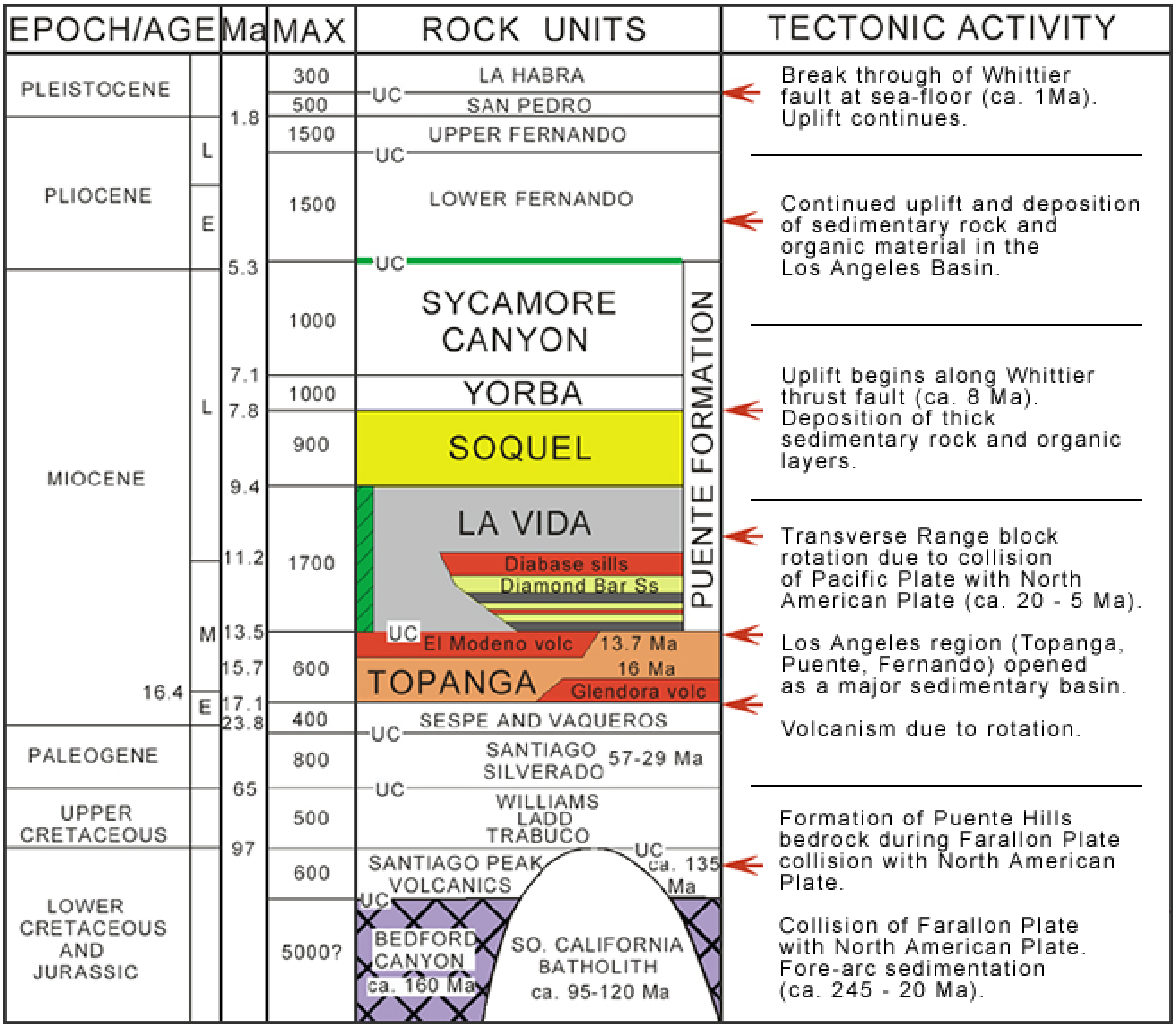

Figure 11: Puente Hills Stratigraphic/Event Column. Illustrates the geologic time frame across rock deposition and tectonic events in the Puente Hills. UC, unconformable, which stands for missing time. Green shaded bar shows major oil source rock interval. (Illustration by Tom Bjorklund and K. Burke, “Four Dimensional Analysis of the Inversion of a half-graben to form the Whittier Fold-Fault System of the Los Angeles Basin,” *Journal of Structural Geology*, 24(2002): 1371.)

Appendix B: Geologic Time Scale

Eon	Era	Period	Series-Epoch	Major Events	Time (Ma)
Phanerozoic	Cenozoic	Neogene	Holocene	**Excluding erosion, climate and Hills emerge in modern form.** Megafauna extinction at Holo/Pleistocene. End of recent glaciation and rise of modern civilization.	0.011430
			Pleistocene	**Emergence of Hills from ocean, ice age climate. Continued Sedimentation and uplift in Hills.** Megafauna mammals flourish. Evolution of anatomically modern humans.	1.806
			Pliocene	**Continued Sedimentation and uplift in Hills.** Intensifying ice age; cool/dry climate.	5.332
			Miocene	**Rotation of Transverse Range blocks. Beginning of Puente Hills Uplift (8 Ma).** **Pacific Plate Collision, transform margin.**	23.03
		Paleogene	Oligocene	**Continuation of Farallon Subduction. Pacific Plate Approaching.** **Climate begins to cool; ice age begins.**	33.9
			Eocene		55.8
			Paleocene		65.5
	Mesozoic	Cretaceous		**Farallon Subduction: sedimentation and volcanism. Formation of Puente Hills' bedrock.** K-T (Dinosaur) extinction event. Breakup of Pangea.	99.6
		Jurassic			199.6
		Triassic		Active Margin NAM. **Farallon Subduction Begins.**	251.0
	Paleozoic	Permian		Active Margin NAM. Permian-Triassic extinction event: 95% of life becomes extinct. Pangea.	299.0
		Carboniferous/Pennsylvanian		Continuation of active margin along Western North America.	318.1
		Carboniferous/Mississippian			359.2
		Devonian		Active margin along western North American (NAM) during Devoian with Island Arc, Terrane accreation, beginning of significant orogeny.	416.0
		Silurian			443.7
		Ordovician			488.3
		Cambrian			542.0
Proterozoic				Oldest rocks in California (1800).	2500
Archean				Stabilization of modern ancestral North American continent of Laurentia.	3800
Hadean				Formation of earth (4570). Oldest known rock (4100).	4570

Events = **Puente Hills**. Events = California/Western North America/World. This table is not to scale. Adapted from the Wikipedia Geologic Time Scale, see: http://en.wikipedia.org/wiki/Geologic_time, for complete table and record of major events.

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