Title
On the Natural Geography of North San Diego County

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ON THE NATURAL GEOGRAPHY OF NORTH SAN DIEGO COUNTY
(Essay prepared for the San Dieguito River Valley Conservancy)

Introduction

When asking incoming students at UCSD to name a native Californian plant, the answer I got was unsatisfactory. Fortunately, there are plenty of good representatives in San Diego County (Figure 1).

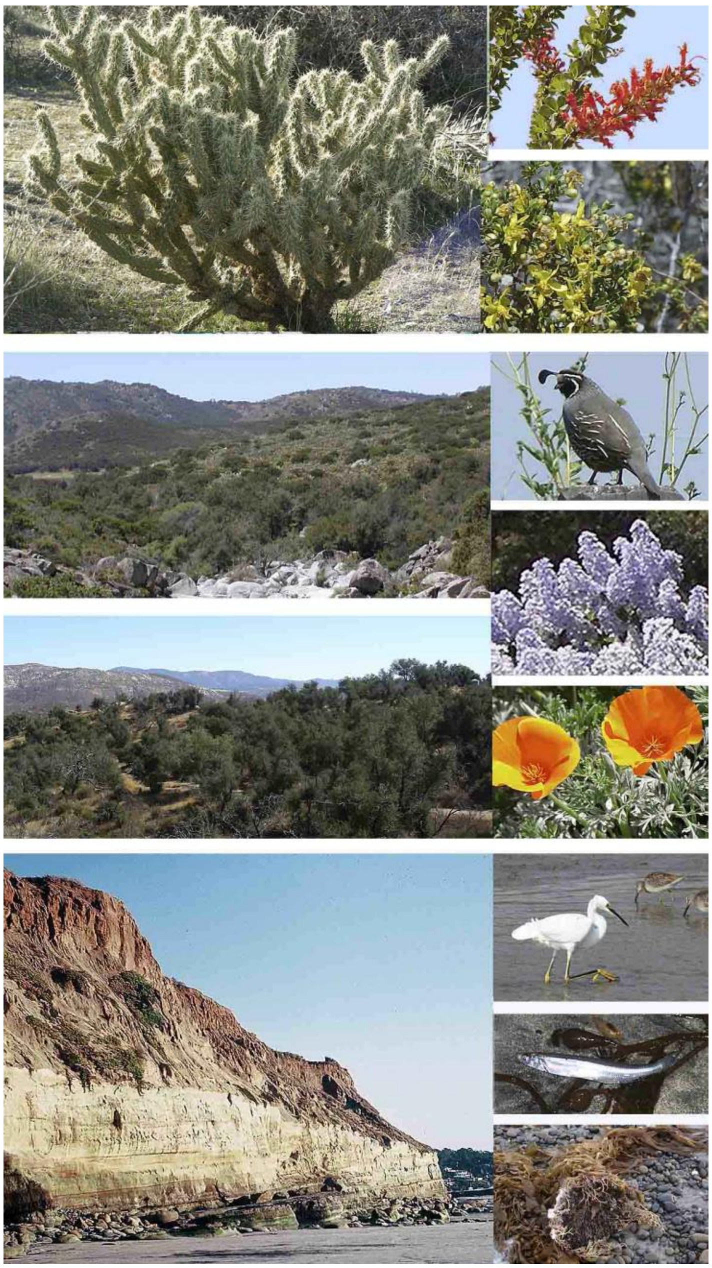

Figure 1. Scenes in San Diego County illustrating the great variety in geographic setting, which is the reason for the presence of enormous biodiversity. Bottom pictures: western area (coastal); top pictures: eastern area (Colorado Desert); center: chaparral and oak groves.

As a consequence of the prevailing geographic diversity, the county has an extraordinary variety of plants and animals. It is an internationally recognized "biodiversity hot spot" and has very few equals in that regard, in all of North America or elsewhere on our planet. The challenge is to get that information out into the public and link it to physical environmental conditions and make it memorable as well. We shall protect what we know and love.

Beach visitors are aware of many of the marine creatures that live along the sea; plant lovers know that there are hundreds of plant types in the county; birders easily count well over a hundred bird species in the county's marshes and lagoons and even just around the reservoirs. In fact, for all types of plants, vertebrates and invertebrates there is an unusually high number of species, reflecting a plethora of ecological communities within the general geographic setting of the county, which is well preserved especially in the center of the county, along the San Dieguito River Valley and beyond (Figure 2).

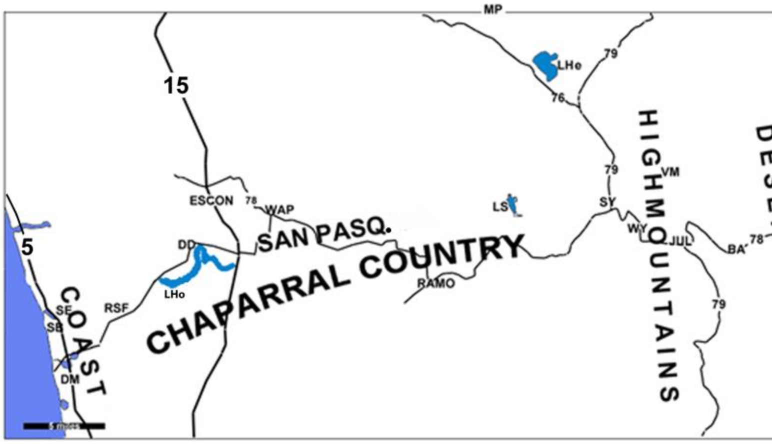

Figure 2. The general layout of the region here visited. Escon., Escondido; San Pasq., San Pasqual Valley. From west to east: DM, Del Mar; SB, Solana Beach; RSF, Rancho Santa Fé; LHo, Lake Hodges; DD, Del Dios; WAP, Wild Animal Park; Ramo., Ramona; LS, Lake Sutherland; MP, Mt. Palomar; LHo, Lake Hodges; SY, Santa Ysabel; VM, Volcan Mtn; WY, Wynola; JUL, Julian; Ba, Banner.

The plant communities succinctly outline the various habitats, including climatic conditions resulting from the varying amount of precipitation within the county. The bulk of the plant cover is chaparral, as befits a semiarid region with a Mediterranean-type flora. (Differences between Chaparral and Coastal Sage Scrub are discussed in Berger, 2013).

The land rises from the coast eastward, cresting at the top of the Peninsular Ranges, near 6000 feet. Beyond the mountains that make the crest, after crossing an enormous fault zone with an associated great and rather sudden drop in elevation, one enters the desert, which begins in the rain shadow of the mountains and extends well beyond San Diego County into the arid zone of the great Southwest that includes Arizona and New Mexico.

Much of the character of the western slope is very accessible for study along the valley of the San Dieguito River, much of which is within the San Dieguito River Park administered by San Diego County and several cities with an interest in the Park area. A formal (albeit highly schematic) separation of the main types of plant cover along this valley has been made by the administration of the San Dieguito River Park (Figure 3). The types shown are salt marsh, coastal sage scrub, chaparral, and oak woodland.

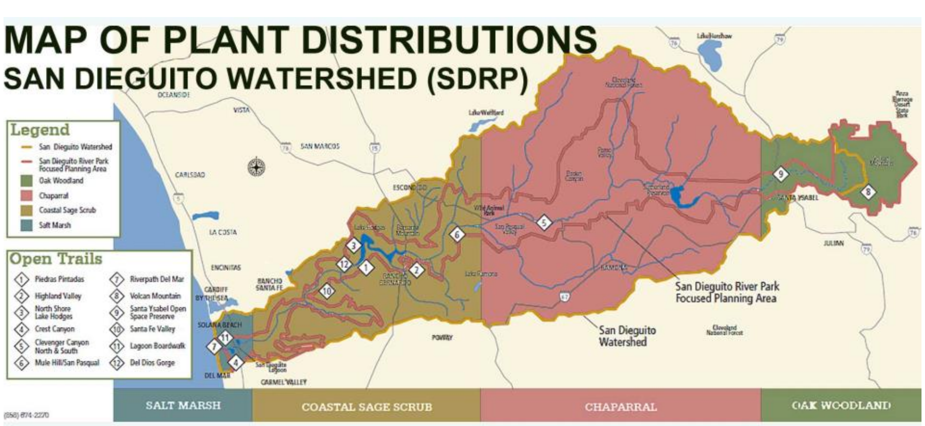

Figure 3. Categories of plant cover distinguished by the San Dieguito River Park. Courtesy SDRP.

In addition to thefour central types of plant cover identified by the SDRP, there are a few others relevant for San Diego County. On the coastal terrace bordering the seashore there is much land heavily impacted by human use, and there are conifer forests at the crest and then the desert beyond the mountains. The plant cover well reflects the major divisions of the physical geography, which is strongly dominated by differences in precipitation (Pryde, 1984). Thus, the plant cover provides the access to the physical geography and the climatology of our region. That it does so all over the world was recognized by the famous German-Russian geographer, botanist and climatologist Vladimir Köppen early in the 20th century. Together with his son-in-law A. Wegener he used information from fossil plants to reconstruct climates of the past (in 1924). Köppen offered a general textbook on climatology, defining the field (1931). His classification of plant cover is still widely used, although a more detailed one (the "Holland" classification") that is appropriate for our region has been applied to mapping the plant cover in San Diego County in recent years (Holland and Keil, 1995; see Oberbauer, 1996).

For the SDRP map of the water shed in the region, important indicator plants for the various associations (salt marsh, coastal sage scrub, chaparral, and oak woodland) are Pickleweed, California Sage Brush, Chamise, and Live Oak, in that order (west to east) (Figure 4).

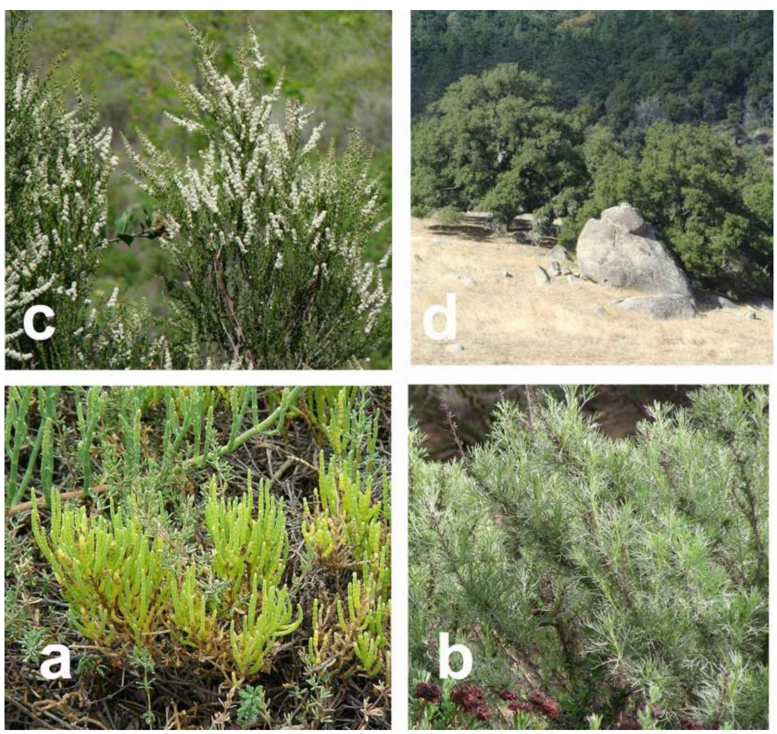

Figure 4. Important plants in the plant communities identified by the San Dieguito River Park. **a***, pickleweed;* **b***, California Sage Brush;* **c***, Chamise (blooming);* **d***, oak groves and woodland. Coastal plants at the bottom (reflecting low elevation).*

Concerning the dominant plants, it is of some interest that the chaparral plant "Chamise" is the single most abundant native plant species in southern California, and that the coastal-sage-scrub plant "California Sage Brush" is not a sage of the Mint family, but belongs with the sunflowers, taxonomically.

On the general climate setting and geologic history

While regional climate is the pattern-maker for the plant cover, the foundation for any given landscape rests within geologic history. Also, the regional climate is embedded in the larger pattern of the global climate. Thus, the general global climate and geologic history are the crucial elements in understanding any natural environment. In the case of San Diego County, the role of the cold California Current offshore must not be forgotten. It is, in the last several million years, a major factor in keeping things dry onshore (10 inches of rainfall, or less), so that the plants in the coastal zone have many aspects of related desert plants. Many of the plants shut down (dry up) in summer – they are "drought deciduous."

Mountains and their foothills take up much of the space in the county. This is the region of the "true" chaparral, the impenetrable bush, and that of groves of live oak. At the coast, in the west where we can see the ocean, there is the beach and there are mesas cut from terraces rimming the sea. Much of this coastal zone is heavily used and impacted by human activities. At the crest there are forests, with deciduous oaks among conifers. The eastern border of San Diego County is in the great southwestern desert ("Colorado Desert") that extends to adjacent counties and to Mexico.

A sampling of the different environments reveals the tremendous diversity of landscapes and living things within the region that is the hallmark of San Diego County, from the kelp forests, lagoons and marshes in the west, to the Cholla- and Ocotillo-bearing drylands in the east (Figure 1). The main controls on this diversity are nutrient supply in the marine realm and precipitation on land. Major short-lived disturbances of long-term patterns – by El Niño and by fires – also play an important role in maintaining diversity. Geologic and climatic histories matter.

The mountains in California are rising all the time, thus maintaining the existing topography over long time spans despite erosion. The uplift, which has been going on for several million years, is largely responsible for the harshness of the desert in the east of the county, by setting up a trap for rain from the sea. In this sense, our desert is a "rain-shadow" desert. However, the land east of the mountains would be dry anyway, mountains or not, because we live in a desert belt generated by the global air circulation. Technically speaking, we are in the downward moving limb of the Hadley Cell (see Figure 5), which takes dry air from high altitudes down to the ground, and heats it on the way down.

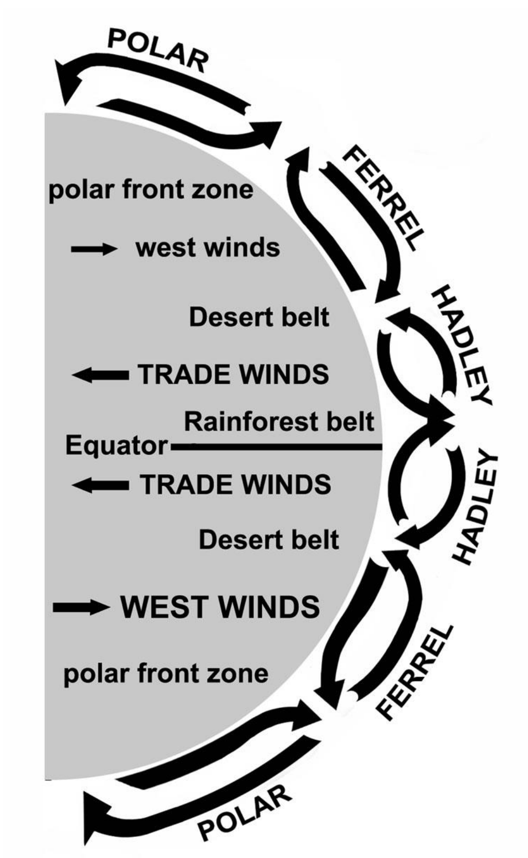

Figure 5. Wind systems on Earth, schematic as latitude-dependent cells in profile. The downward limb of Hadley and Ferrel cells define the desert belt (as a high-air- pressure belt).

Even on the western side of the mountains, where there is no rain shadow, we have a dry zone with very modest rainfall. The vegetation here is of a special kind. It is classified as typical for a “Mediterranean” climate, along with the vegetation in certain parts of Australia and South Africa – and of course southern France, Spain, Italy, and Greece. The “Mediterranean”-type vegetation is generally resistant to drought and is adapted to sporadic fires, by re-sprouting from the roots and by making seeds that are activated by the heat of fire, depending on the type of plant. Naturally, plants imported from all sorts of drylands in other parts of the world, and especially from other “Mediterranean” regions, feel very much at home in San Diego County and do very well, especially if their natural enemies have been left behind.

In arid regions the vegetation cover is sparse and the soil is thin in many places, and the geologic underground is readily studied. Mainly, in San Diego County, we see granitic rocks wherever there is no soil (Figure 6).

Figure 6. Granitic rocks of the Southern California Batholith exposed by drought and fire. The rounding is from weathering.

The bulk of the rocks of San Diego County belong to the “Peninsular Range.” Geologically, the rocks define the “Southern California Batholith.” The Range is made by the batholith. It continues southward across the border into Baja California (Figure 7). “Batholith” is a technical term based on Greek words for “deep” and “rock.” These are rocks that had their origin many miles down within the Earth, in the roots of an ancient mountain chain. They are “igneous” rocks, shaped by high temperature and pressure. (The technical word “igneous” has *fire* in it, as in “ignition.”) Obviously the rocks, having been formed at great depth and now seen at the surface, were uplifted by many miles.

The rocks of the Batholith Range are similar to rocks found in the Sierra Nevada. They are generally granitic in nature. Technically, they are mostly “granodiorites” or “tonalites” (closely related rock types) being rather rich in dark minerals and not quite as rich in quartz as is regular granite. Also, there are other rock types, as befits the complicated origins of the mountain roots that resulted in the batholith.

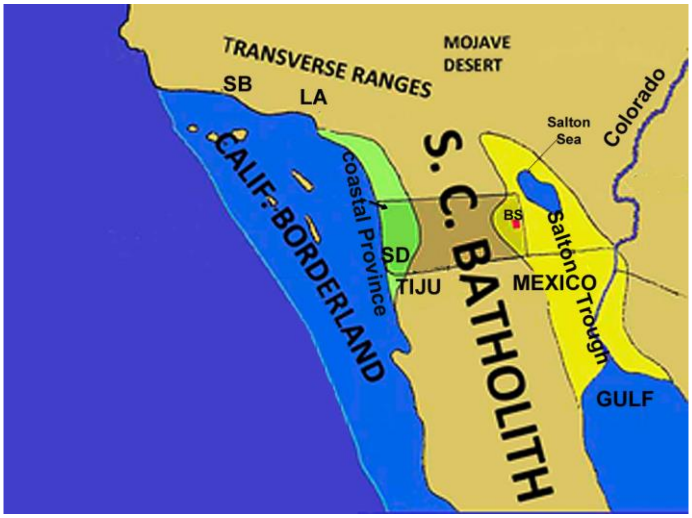

Figure 7. General geologic and geographic setting of San Diego County and Southern California (S.C.). SD, San Diego; BS, Borrego Springs; SB, Santa Barbara; LA, Los Angeles; TIJU, Tijuana. The area of San Diego County is shown darkened for recognition. The Southern California batholith (a geologic feature) makes the Peninsular Range (a geographic feature).

Quite generally, as we climb up toward the crest of our mountains, or any other mountains, we tend to find older rocks from deeper in the crust. The reason is simply this: mountains represent the culmination of rising crust, and overlying younger material has been removed by erosion (Figure 8). The removal, by unloading the rising crust and thus decreasing downward pressure, results in yet more rising. Thus, there is positive feedback on the rising of crust. It takes a long time to flatten a mountain.

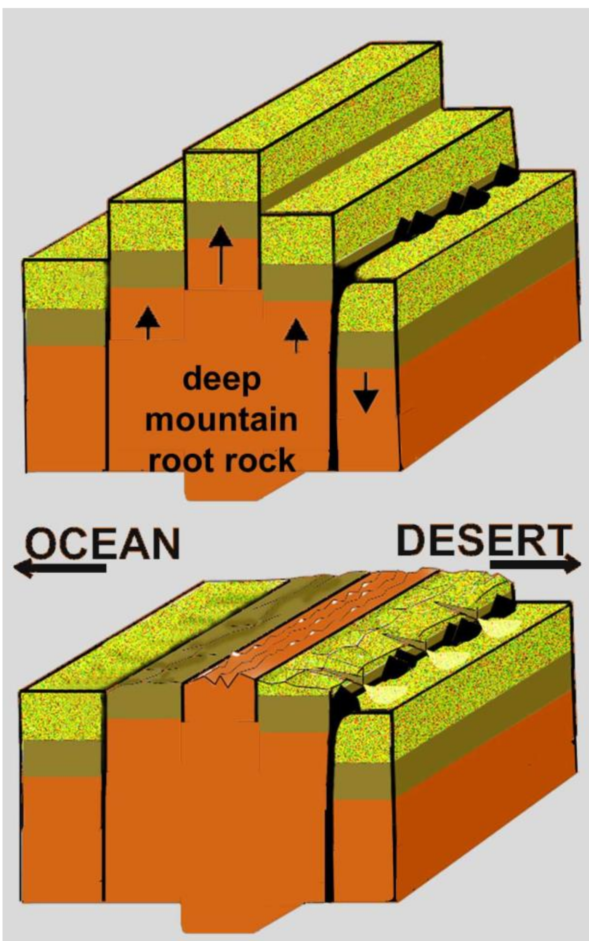

Figure 8. Schematic of the origin of high mountains in California. Uplift moves the deep rocks in the center of the range to high positions, where they are found exposed after the overburden (sedimentary rock) has been removed. Some faults along the range may leak lava (as seen in the Mojave Desert).

In places, San Diego County's granitic rocks have lens-shaped inclusions of dark rock. The dark material presumably was ripped off from surrounding crust below the ancient mountains, at the time of the origin of the granitic rocks of the batholith (largely the "plutons" within the batholith) in the great deep melting zones of a collision zone (Figure 9).

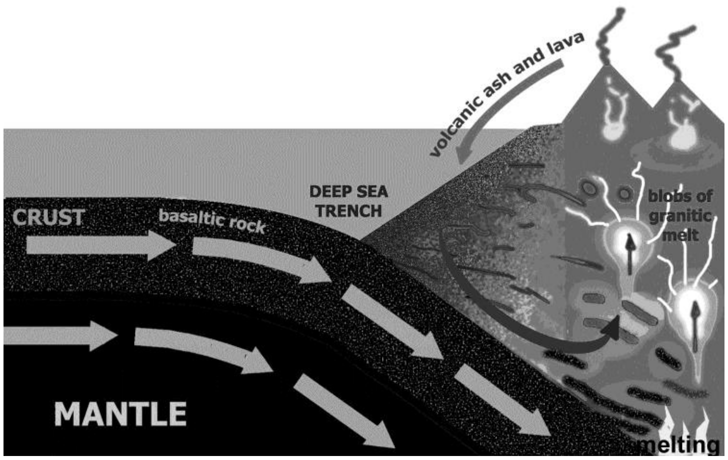

Figure 9. Idealized cross section through a collision zone of the type found along the western margin of the Americas (collision of sea floor with continent). Note the presence of a trench and of volcanic activity. The blobs of granite rising from the deep melting zone (short arrows) get stuck within the mountains and cool there. They are exposed as peaks and hills after the mountains have been lowered by erosion (and the volcanoes removed). From Berger, 2009.

That a zone where crust moves downward into the mantle (by "subduction") results in a mountain chain displaying high elevation may surprise. There is, of course, the deep trench offshore. However, the piling up of less dense rock landward of the trench (rocks that melt more easily and rocks from previous melting and erosion cycles) eventually produces uplift. The reason is that the less dense rock is pushed up by the denser rock below it. The analogy is to a floating submerged object in water, held down by an external force, and seeking a shallower level when released. As mentioned, the more material is removed by erosion, the more the countryside rises in response to the offloading.

The process of the type of collision shown in Figure 9 now is ancient geologic history in San Diego County. But it can still be studied in northernmost California and beyond, in Alaska, and in the western mountains of South America, notably those of Peru and Chile. It is from such studies that geologists are able to reconstruct what the geologic environment must have looked like here in the distant past.

Hundred million years is a long time. Dinosaurs were roaming the countryside then. The cover of the original Jurassic and Cretaceous mountains in San Diego County, and with it the volcanic material, has long been removed by erosion. (For a geologic time scale, see the Appendix, Figure A1.) "Volcan Mountain" near Julian, in the highlands of San Diego County, is made largely of granitic rocks, by the way. The name has no geologic implications.

But even though the collision that shaped San Diego County millions of years ago has long ceased, we find much of its evidence still, all over the county. I am referring to the presence of plutons, now seen as shapely hills made of granitic rock (Figure 10). Plutons are fossil balloons of hot igneous rock that once rose through mountain roots, melting their way toward the surface. After cooling, and thus losing their buoyancy and their power to melt the surroundings, they got stuck. Much later they were exhumed by erosion and now provide for hills and bumps in the landscape. What they tell us is that in this landscape we are walking on mountain roots.

Figure 10. A typical hill in San Diego County, made of granitic rocks, suggesting an origin as a pluton. Photo taken Near San Pasqual Valley.

Geography and ecology as a result of geology

Why is the geologic background so important in understanding the geography of San Diego County?

Geology is important because the existing topography is a result of geologic history. Perhaps the best-known illustration of this principle is in the cliffs of the county at the shoreline (Figure 11). More people are familiar with the cliffs, presumably, than with all the other topographic features of the county, judging from where visitors and vacationers congregate.

Figure 11. Cliffs rimming the Pacific in northern San Diego County. Left: La Jolla. Right: Del Mar.

The cliffs document the general rise of the land. Their origin is a product of both general uplift and wave attack (Figure 12). The uplift prevents the sea from moving in on the land by carving a terrace at beach level way into the continent. This apparently did happen in the distant past during a cessation of uplift and the resulting terrace was covered with sediments (as seen on the flat elevated areas once near sea level). The main terrace that today is largely settled, the Linda Vista Terrace of coastal San Diego County, is covered by lagoonal and coastal delta deposits.

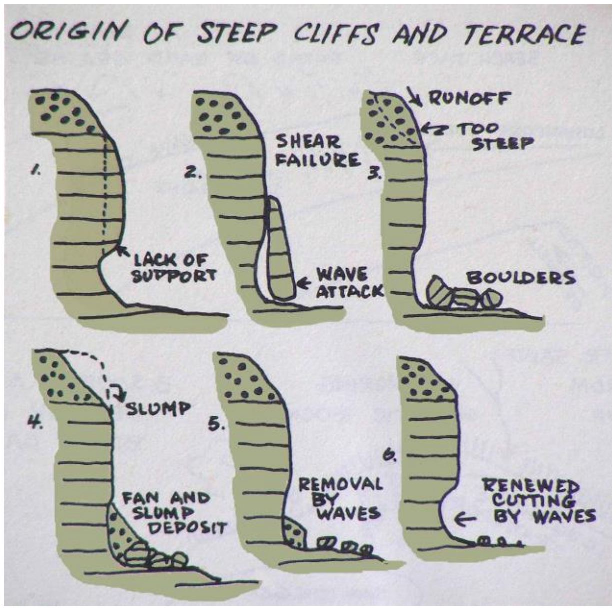

Figure 12. Schematic of the origin of steep cliffs, as a product of both uplift and wave attack, and the wave-cut terrace in front of it. From Berger, 2007.

The cliffs are a prime example of ongoing geologic processes, and readily observable. The same is true for the beach. The sand is brought in by flooding rivers together with lots of mud that is removed by the waves and dumped offshore. The remaining sand forms a thin veneer on top of the wave-cut terrace near sea level (Figure 13). The waves, besides washing the sand, move it southward, since the winter waves, which do most of the work, come from the north.

The wind normally has a northerly component all through the year, a fact that is responsible for the California Current running southward. The Current brings cool water from northern latitudes, and also pumps cold water upward, just off the shore. As mentioned, the low temperature of the water offshore is one more reason for a dry countryside next to the sea: cold air does not carry much water.

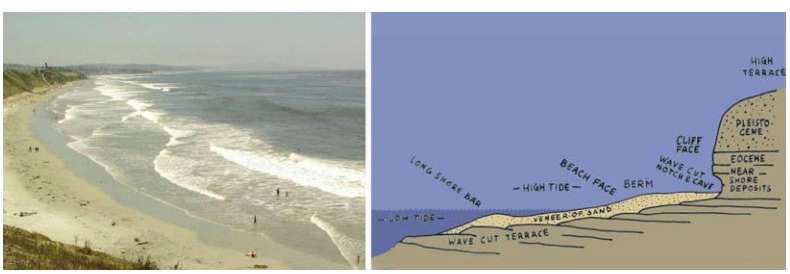

Figure 13. Nature of the beach in northern San Diego County. Left: general view. Right: schematic profile. The veneer is typically only five feet thick.

The geography and ecology of the county in general reflect past and ongoing geologic processes. At the shore these processes provide for an abundance of rocks for organisms to grow on – masses of barnacles and mussels, among others. Also, these processes deliver the sand – an important habitat for certain crabs, worms, bivalves, and snails.

Regarding the plant cover on land, the most important effect of geology is the fact that topography guides precipitation and thus plant growth. In addition, geology determines the nature of the soil. The rock types within the mountains are responsible for making the plant-bearing soil what it is, as they disintegrate in the attack of rain water and by the roots of plants aided by the fungi attached to the roots.

That topography controls much of the patterns of precipitation in the county is readily appreciated (Figure 14). Landward moving water-bearing air has to rise to climb the barrier that is posed by the mountains. As the air rises, it expands and cools, and much of the moisture it carries must then condense, making clouds. Clouds can bring rain, but they do not necessarily do so; they may dissolve again east of the mountain crest after crossing the crest in the wind. In the coastal zone we get plenty of low clouds (or “fog”) at certain times in the year. Nevertheless, the coastal zone receives very little rain.

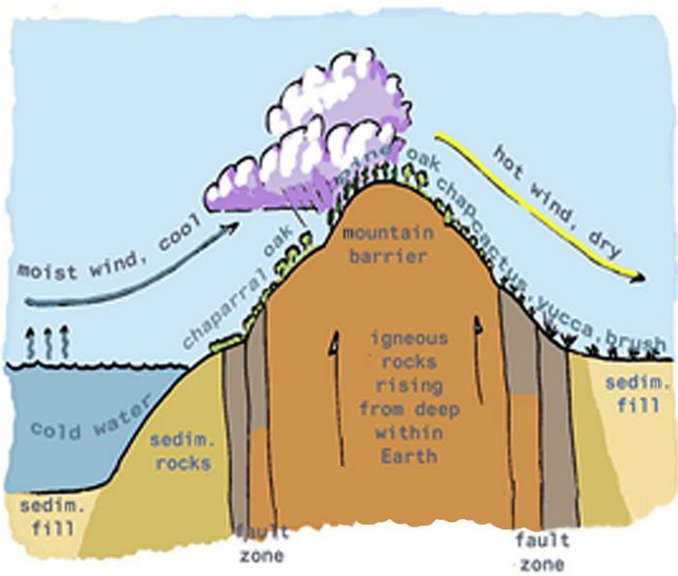

Figure 14. Plant zonation by elevation. Marine air cools as it rises. When the air is cold enough, clouds form. Dry air descends into the desert, It heats up on falling. It dries out the soil rather than bringing moisture. After Pryde (1984), greatly modified.

As we climb up to the higher elevations generated by the general uplift, we are likely to encounter running water (Figure 15). Unfailingly, a creek will be bordered by riparian vegetation, such as willows.

Figure 15. Running water in the upper elevations of San Dieguito River Park. (Santa Ysabel Creek, near Lake Sutherland.)

Of course, it is not strictly necessary for the water to be running to support riparian vegetation, but it helps. Drinking the water is not recommended. There may be cattle or sheep nearby and close to the water course at times.

Realizing that running water is likely to be available at high elevations, we now appreciate one more reason why people migrated seasonally up into the mountains, for thousands of years in the past. Presumably it was not just the acorns that they were after, although we readily find evidence for that at high altitudes. We can be reasonably sure that they were after the running water as well. All camps need water, and for this reason the San Dieguito River Valley is a treasure chest for archeologists. Among these treasures (even at relatively low elevations) are rocks painted centuries ago (*piedras pintadas*), many types of tools, hunting implements, and a host of kitchen utensils.

How did people survive in the desert? After all, east of Volcan Mountain there is hardly any rain, and when there is water it tends to come as floods. East of the crest, the San Felipe Valley is the first large dryland basin with abundant chaparral and desert plants (to be discussed below). It does get river water from nearby mountains; thus it was habitable for that reason. Much of the water used by people in the desert must have come from springs. That there are a large number of these in the county is evident from the many places that have the word "Springs" in their name. The desert east of San Felipe Valley, for example, has "Borrego Springs." Some of the springs in San Diego County produce hot water – a sign that the spring water was recently in contact with hot rocks underground, not far below the surface.

Both the coastal zone and the foothills are semi-arid, with some 10 inches of rain each year, or slightly more in the foothills, while the mountains have springs, forests and green meadows, with some 30 inches of rain. The low desert east of the mountains has only a very measly allotment of life-giving rain, a few inches annually. In addition, the dry falling wind provides for increased evaporation. Much of the desert is in the rain shadow of the mountains. After the air has lost much of its water, it can turn exceedingly dry on the way back down into the desert. Of course, while falling, the air is compressed and heats up. Hot, dry air removes moisture from the soil and from plants it comes in contact with.

Seasons matter. They control the precipitation cycle; that is, the rain and snow, which come late in winter. At lower elevations, on the western side of the Range, oaks keep their leaves all year long – it takes water to grow leaves in the first place. At high elevations there is snow and frost to reckon with.

The earthquakes in California remind us that the processes involved in making mountains have not ceased, but that the land is still "tectonically active." The ongoing uplift of the mountains of San Diego is part of this activity.

The Importance of Upwelling

The California Current is cold relative to its surroundings because the origin of its waters is in the north. The surface waters move southward along the coast because of the northeastern Pacific high pressure region, which is at the center of "anticyclonic" winds (Figure 16). The atmospheric High is strongly expressed in summer. The southward moving winds both drive the current and move surface water offshore thanks to the Earth's rotation. The offshore movement sets up a process called "upwelling" of subsurface waters, which rise to replace the surface water moving offshore. This upwelled water is quite cold, as is well appreciated by surfers; they mostly wear dark wet suits to keep warm.

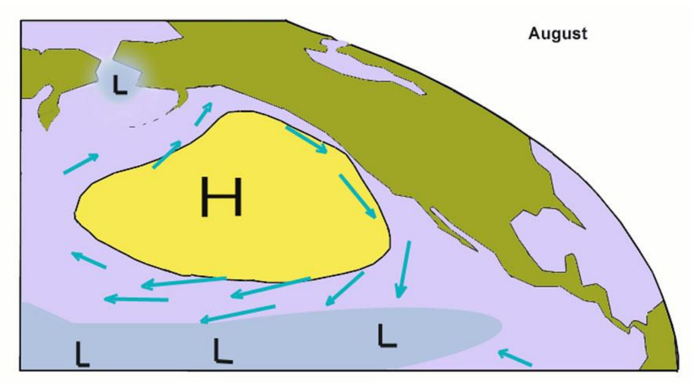

Figure 16. The California Current is driven by the NE Pacific high pressure field, well expressed in August, with trade winds moving westward off Baja California. After G. Dietrich, adapted from Berger (2009). H, high air pressure; L, low air pressure.

Even in summer the near-shore waters are quite cool, as is quite evident when swimming in the La Jolla Cove or anywhere along the shores of San Diego County. The really cold water is restricted to a rather narrow band along the coast. Farther out to sea the surface waters are warm in summer, having been heated by the sun. The growth of minute algae ("phytoplankton") reflects the change of intensity of production that goes parallel with temperature: the coastal strip of the sea is greenish while the deep open ocean is blue. In addition, kelp forests (giant algae) grow along the shore where the water is cold and nutrient-rich. The connection between temperature and nutrients is intriguing; it will be discussed below.

The contrast between warm and cold surface waters along the coast has yet another interesting corollary, besides the implications for the productivity of the coastal ocean. Warm onshore winds carry large amounts of moisture as vapor. When air cools over the coastal strip, it loses its ability to hold much of that vapor. The water emerges from the air as fog. The fog is trapped in the layer of cool coastal air. It can bring moisture to plants in the coastal zone. This may be one reason why the Torrey Pine has long needles: to capture fog moisture.

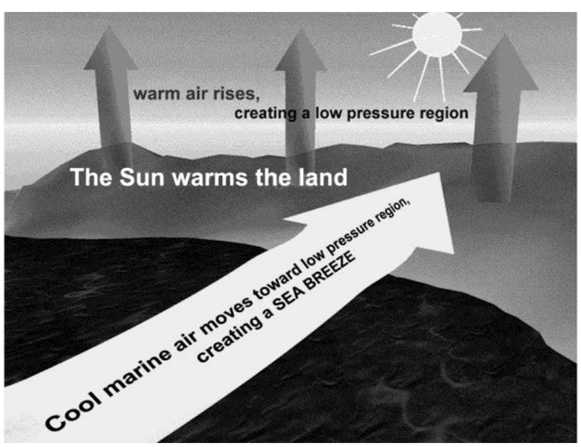

Figure 17. Schematic of the sea breeze. It has to rise at the cliffs and thus supports the gliding of pelicans and of hang-gliding enthusiasts. Source: NASA figure, modified.

There is wind coming from the sea practically every day (the "sea breeze," Figure 17). It is a response of the coastal climate system to the heating of land by a high-standing sun. This wind does not foster the upwelling of cold water. Commonly, it consists of air that is cooled by upwelled water.

Back to the productivity aspects. The phenomenon of "upwelling" is essential to the seabirds, which are quite abundant on the shores of the county, on account of the fact that upwelling means food. The cool upwelling water brings nutrients into the sunlit zone (the uppermost layer of water) where minute green bacteria and algae thrive (Figure 18). They serve as food for small crustaceans ("copepods") and for a host of other small creatures. Altogether, the mixture of small organisms makes a nutritious broth for the many filtering organisms growing on rocks at the shore or hiding within the sand. Also, a rich supply of plankton feeds the fish that feed the pelicans and the cormorants. The marine "food chain" starts with nutrients and runs up to birds and seals here in San Diego County.

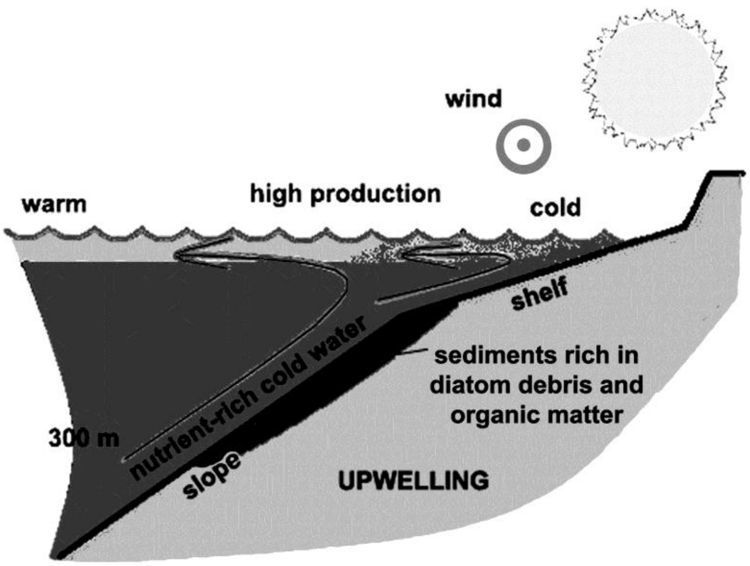

Figure 18. Schematic of the upwelling process of southern California. The wind is mainly toward the observer (target symbol); the current has an offshore component because of the Earth's rotation.

The upwelling, being a result of the prevailing winds and currents, can shut down when the winds cease or reverse direction and when the prevailing currents weaken. The well-known illustration of such shut-down is the El-Niño phenomenon (Figure 19). "El Niño" is Castilian Spanish and means "the child," referring to the Christ at Christmas, when the shutdown is most in evidence in the years when it happens. (The correct English transcription would be "El Ninyo,"in analogy to the words "canyon" and "pinyon." The term "El Nino," used in some newspapers, is incorrect.)

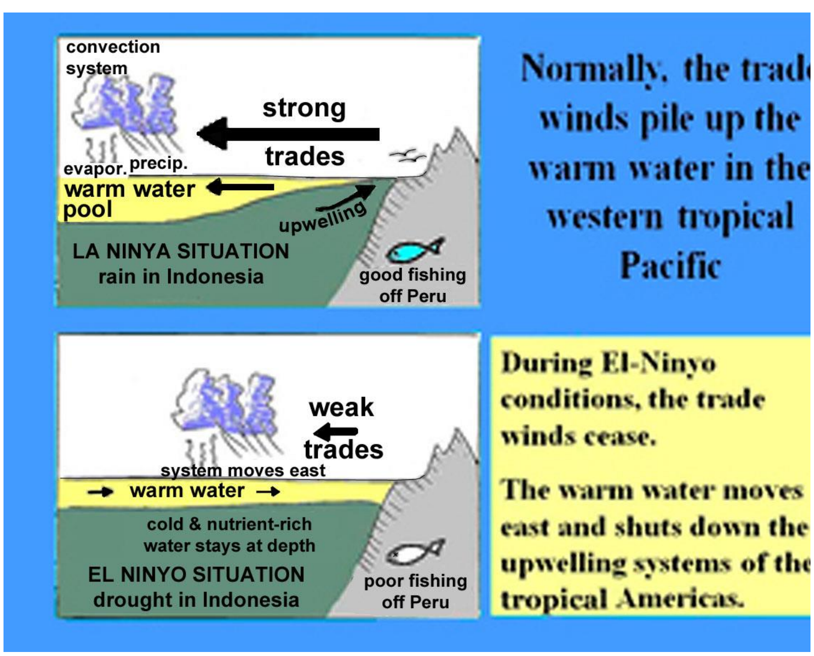

Figure 19. The shutting down of upwelling from a failing of trade winds ("El Niño") involves a spreading of a tropical warm-water layer toward the eastern tropical Pacific (along with rain) and from there to the region off California. The process affects fishing off Peru and along much of the West Coast. The opposite situation (with lots of upwelling off Peru and Chile, and also California) has been dubbed "La Niña," for contrast.

Drought is pervasive in San Diego County. Among the chaparral's many drought-adapted plants are a great number that have close relatives in the desert. The most conspicuous among these are the yuccas and other members of the agave family and the many different types of cacti (Figure 20).

Figure 20. Desert plants east of the central mountains: Mojave Yucca, Beavertail cactus, Agave and Barrel cactus. Similar plants occur in water-deficient places along the coast and in the chaparral on the western slopes of the mountain range.

Commonly, areas with distinct differences in the availability of water have different species of plants, albeit species that may be closely related. But in some cases, as in several types of yucca, the same species are seen in various environments. Clearly, such broadly adapted species should do well whenever the climate changes.

The word "chaparral," incidentally, ultimately derives from a Spanish term for impenetrable brush-cover rich in scrub oak. Many botanists restrict the label to that type of cover, or else plant communities much like it away from the coast and present in the foothills well above the coastal terrace. For the plant associations in the coastal zone and rich in drought-deciduous plants they use "Coastal Sage Scrub" or related monikers. There is much to be said, of course, for distinguishing the soft scrub along the coast from the hard one that tears at one's clothes farther inland. However, there is an enormous overlap in the species within both types of plant cover. Abundances change gradually and there are no sharp boundaries. The lack of strict ecosystem boundaries in the chaparral encourages the use of the label "Coastal Chaparral," a term that is perfectly understandable. In language, usage is king, not necessarily logic or superior classification.

Coastal Chaparral is the type of plant cover most at risk from human impact. Along much of the coastal strip of San Diego County, in fact, the land is developed and many gardens carry a foreign flora originating in the Mediterranean realm, in South Africa, in South America, or in Australia. Plants that have escaped from the gardens and now mix with natives, crowding them in places, are commonly referred to as "invasives" by botanists. The most conspicuous invasives are various species of *Eucalyptus* (from Australia), and many types of African daisies and ice plant.

That the Coastal Chaparral is largely overprinted by development readily emerges when studying maps of plant distributions in San Diego County, such as maps produced or sponsored by SANDAG. Also, as a result of such study the "hard" or "true" chaparral (the one that largely consists of perennial plants and of woody shrubs) comes into view as the dominant plant cover in San Diego County.

Of course, "chaparral" is just a convenient name – there are many different plant communities involved. The labels "Chamise chaparral," "Manzanita chaparral," "Scrub oak chaparral," "*Ceanothus* chaparral" and similar ones, including "Mixed" chaparral, reflect such differences with respect to the dominant plant. Noting the plant distributions, we soon appreciate that elevation and rainfall are not the only important factors in controlling them. Exposure to the sun is important, with south-facing slopes being commonly much drier than the north-facing ones. Thus, the use of plant cover as an index for the regional climate has some limitations stemming from local conditions.

In addition to physical determinants of the plant cover there are complicated biological environmental determinants. Their history adds a strong element of chance to the patterns. Once a species of plant has established itself as the dominant cover, it restricts the growth of certain co-occurring species and thus favors the growth of others. Also, the nature of the soil is of crucial importance: some plants will not grow unless the right kinds of materials and fungi are present in the soil. All plants need nutrients of various specific types, some of which are directly linked to the geologic nature of the ground bearing the soil.

More subtle, yet clearly noticeable, is the effect of large rocks on the local vegetation. Such rocks provide shade and shelter from drying winds, and they slow evaporation of moisture from the soil they cover. Also, they may gather dew because of their rapid cooling at night. In any case, large shrubs and some trees seem to prefer the vicinity of the rocks, illustrating the importance of seemingly minor environmental differences (including the local "microclimate").

The most abundant plant in the county is "Chamise" (*Adenostoma fasciculatum*) a woody bush with tiny leaves and (in spring) with spired bunches of small white flowers (Figure 21). The name "chamise" is said to mean "firewood." This would fit with the vernacular American term "greasewood," which refers to several plants that burn well, including *Adenostoma fasciculatum. I*n many places, it is the dominant plant in the local chaparral*.*

Figure 21. "Chamise" or "greasewood" (Adenostoma fasciculatum); the most abundant plant in the chaparral of San Diego County.

Chamise is highly resistant to drought and to fire (as are other chaparral plants). The plant dries up when water is lacking. Also, it re-grows from root stock after a fire. Presumably the adaptation to drought is the original one in the history of the development of the plant, on the time scale of evolution (millions of years),

The prettiest of the typical chaparral plants is the "California Lilac," comprising several species of the genus *Ceanothus* (not a lilac, by the way). When this plant blooms (early in spring) it can paint the entire hillside in a delicate blue or violet hue (Figure 22).

Figure 22. Ceanothus chaparral (near Julian. in April 2013).

Ceanothus is a genus with a multitude of species. It is in any case a most attractive plant. Representatives are in many gardens in the county, planted there by people who believe in growing native plants (which have the advantage, among other things, of needing very little water).

The only other plant that comes close in providing for a beautiful type of chaparral during flowering is the Manzanita (genus *Arctostaphylos*) with its reddish bark and white (to faintly pink) flowers (Figure 23). This genus also has a great number of species within it.

Figure 23. Manzanita in the chaparral near Julian (left, Nov., right, April).

In the Coastal Sage Scrub the dominant plant is the California Sagebrush (*Artemisia californica*; Figure 24). It has a strong sage-type fragrance, but is not counted among the "true" sages of the genus *Salvia*, as mentioned). It is called "chamizo" in Baja California, according to the botanist Jon Rebman at the San Diego Natural History Museum (Rebman and Roberts, 2012). The varying use of "chamise" and "chamizo" north and south of the border suggests that the term did not designate a particular species of plant in the first place.

Figure 24. California Sagebrush (Artemisia californica). This is the name-giving plant of the Coastal Sage Scrub.

Representatives of the genus *Artemisia* are found in the great sage lands of the West, albeit not the Californian kind. When Zane Grey referred to breast-high plants of sage in the West, he likely had *Artemisia* in mind. His reference to "purple sage" in the title of his famous book conceivably is to a species of *Salvia* with purple flowers. However, in the West everything takes on a purple hue at a distance, even greenish-gray sagebrush. Thus, purple flowers may not be necessary to explain Zane's use of the term "purple sage," while distance of observation may contain the clue.

The "Coastal Sage Scrub," for its name, calls on the abundant presence of the "California Sagebrush" rather than on the true sage plants, which are present also in the Coastal Chaparral (Figure 25). In fact such sages can be seen just about everywhere in San Diego County. Thus, they presumably are not indicative of any particular type of plant association in the county.

Figure 25. True sage plants (genus Salvia). Left: Black sage (abundant in the Coastal Sage Srub). Right: White sage (also abundant at higher elevations).

In addition to the various chaparral types mentioned so far, there is the "Mixed chaparral," in the foothills and in the mountains. It is a true chaparral rather than a coastal one. As the name implies, this type of community is difficult to label. In fact, difficulties in labeling are a very common conundrum when trying to find monikers for a given type of chaparral, because of the enormous diversity involved.

To illustrate, the Mixed chaparral contains, in many places, spectacular large specimens of plants of the sumac family, notably Lemonadeberry (and the closely related Sugarbush) and Laurel Sumac (Figure 26). These particular sumac plants can and do attain tree size when fully grown.

Figure 26. Lemonadeberry ("Rhus integrifolia"; left) and Laurel Sumac (Malosma laurina; right), two large sumac plants, conspicuous in both Soft and Hard chaparral.

Another large bush, easily confused with the sumacs by the uninitiated, but not closely related, is the "Toyon" or "California Holly" (Figure 27). A common member of "Mixed chaparral," the "California Holly" is readily distinguished from similar sumac plants by its hard and slightly serrated leaves. In fall, its abundant red berries attract certain birds, which spread the Toyon seeds in return for being fed.

Figure 27. The Toyon or California Holly (Heteromeles arbutifolia) bears berries in winter. Common in both the coastal zone and in hard chaparral.

Drought and Fire

The most telling properties of the plants growing at elevations above the wetlands in San Diego County have to do with their adaptations to a lack of water and to fire; that is to drought and its ramifications (Figure 28). This is true for the members of all plant communities on land in our region, from the Soft Chaparral or "Coastal Sage Scrub" to the Hard Chaparral or "true Chaparral" and to the plants in the desert. All the plants involved "know" about fire in their genes, even some of the plants at high elevations are known to be adapted to occasional firestorms, despite the relatively high precipitation.

Figure 28. Most large plants in the chaparral are able to re-grow from roots after a fire. (Here: sumac bushes near Lake Sutherland.)

The study of drought and fire has gained new urgency from the expectation, based on climate modeling, that the future will bring more drought, together with the experience commonly expressed in news media that drought results in an increase in the frequency of fire events. Great fires have ravaged San Diego County in recent years. Some of the evidence is still seen both on Volcan Mountain and at the Cuyamaca Rancho State Park in the shape of blackened tree trunks and tree skeletons. Notably the enormous fire of 2003 (the "Cedar Fire") has left its mark, killing many trees. It was the most intense of such fires in centuries. Less fierce ones are quite common in the local forests, on a scale of several decades. The severity of the "Cedar Fire" has been ascribed to the buildup of fuel as a result of fire prevention and to the conversion of trees to firewood by beetles. The beetles do well during times of drought, when trees are stressed and are less able to defend themselves by producing appropriate chemicals and abundant resin for clogging the mouthparts of insect pests. Also, warm winters favor the survival of insects and their larvae.

The "Cedar Fire" raged over much of San Diego County. It killed more than a dozen people and burned a great number of homes. Thick smoke came to the coast and caused concern even in coastal communities not particularly close to fire centers. The fire killed many of the big trees in the Cuyamaca Park, along with smaller ones and bushes. Many big trees are normally just charred at the base during a regular fire, being protected by a thick bark. Recovery has been slow.

There is no doubt that the geographic variation that supports the plant diversity, and all other diversity that is based on the difference in plant communities, owes mainly to the fact that there is an enormous range in water availability and in rainfall, with minima in the desert and maxima near the crest of the central Range. Also, there is no doubt that fire events affect the plant cover over many decades, with great fires leaving a proportionally important legacy for changes in plant cover and associated animals (Diffendorfer et al., 2008). In modern times, the potential for converting chaparral plant cover to grasslands with non-native grass species is especially noteworthy.

Traditionally, drought (and the associated sporadic outbreak of fire storms) is ultimately responsible for a mosaic pattern in the vegetation cover in much of the county. The pattern is especially clear in the rain shadow of Volcan Mountain (Figure 29); but it is apparent for much of the chaparral everywhere. The history of relatively dry and not so dry years, and the accompanying fire events, leave their mark by generating a chain of growth of different species following the clearing of the land of dominant species – what is referred to as "succession." At the end of the succession is the "climax" community, whose composition is difficult to predict, the preceding succession being largely a matter of contingency; that is, rather unpredictable rainfall patterns, available seeds, and the abundance of live roots of previously dominant species that re-sprout from roots after a fire.

Figure 29 Mosaic of plant cover from successions of plant growth after different fires. A scene seen from Banner Grade, east of Julian, looking toward Volcan Mountain.

What is evident to all observers, however, is that the availability of water is the crucial factor in all biodiversity patterns in the county, whether on the western or the eastern side of the main mountain range. Even on the western side, albeit less dry than the eastern one, plants are desperate for water. In many places partway up to the mountains, one notices greenery in dry ravines (Figure 30), such as oak trees and chaparral plants. Evidently the occasional runoff from cloud bursts is enough to maintain this pattern – there is moisture here that is lacking elsewhere. Differences in exposure to the sun (north- versus south-facing slopes) presumably also play a role in establishing and maintaining these plant clusters. In any case, there is slightly more shadow in the ravines, and parching winds are less aggressive here.

Figure 30. Congregation of Live Oak in a ravine in Clevenger Canyon, east of Pasqual Valley, on the side exposed to the sun.

There would seem to plenty of water around, in the nearby sea to the west. However, to become available to plants, the water needs to enter the air by evaporation, a process made more difficult when the sea is cold. And much of the water vapor produced by evaporation is lifted up high toward the crest of the mountains (Figure 31). The plants on the western slope receive leftovers. The water that runs down from the crest is (a) channeled, and (b) subject to losses. The plants themselves aid evaporation by using deep roots to access the water that is present, and moving it into the leaves where the sun can get at it. The process is part of “transpiration;” that is, evaporation aided by plants.

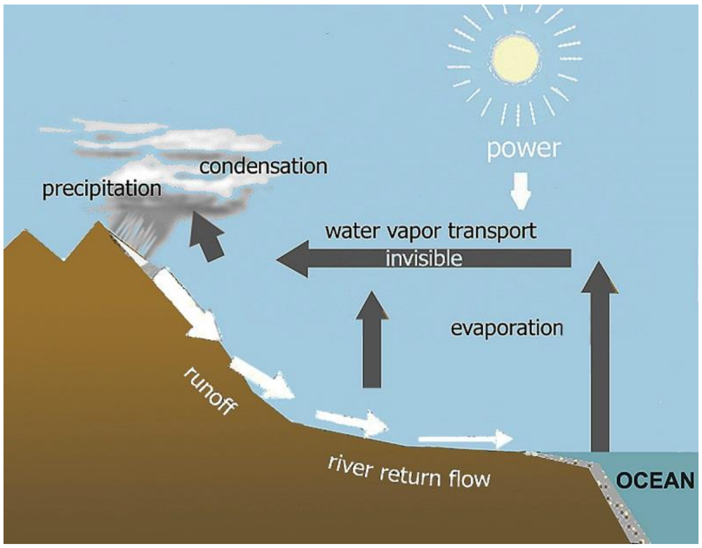

Figure 31. The water cycle on the western slope in southern California. Note that evaporation not only takes place over the sea but also on land.

Strikingly beautiful flowers appear in the many annuals that appear in the chaparral, especially in spring after rain. Many of the various annuals are especially conspicuous after a fire has cleared an area of brush and trees. Bushes and trees prevent smaller species from growing, by shading the ground and also by making the soil unsuitable for competitors.

Thus the main role of fire in boosting biodiversity: the fire removes the prevailing species that have taken over, making room for less dominant species. The aforementioned “succession” commonly involves the removal of the dominant forms by a disturbance such as a fire. A succession starts with colonizing species and ends with a new climax, which is not necessarily the same plant association as before the fire, although survivors among the large plants tend to recover rather effectively (Figure 32).

Figure 32. Re-growth after fires. Left: large sumac plants regrow from roots. Right: new growth on trunks and branches of Live Oak.

Extremely hot fires, such as are experienced during severe drought following a more benign time (when plants can grow and make fuel) may prevent regrowth by killing entire plants. In that case, the association may change completely, presumably toward more drought-resistant forms, if drought is prevalent (or becomes so with climate change). Biodiversity may suffer rather than benefit from fire in such circumstances.

Desert High and Low

It is but a small step from the prevailing semiarid conditions on the coastal terraces and on the slopes of the mountainous regions into the desert environment where drought reigns supremely and permanently. The deserts of eastern San Diego County comprise rain-shadow country, as well as portions of the great Colorado Desert above and below sea level. In the northern half of San Diego County, we are dealing with the "high desert," which includes San Felipe Valley and the upper part of the great Anza-Borrego State Park, and the "low desert," most of which is in the Park, except for a strip of low desert next to the "Salton Sea," a great land-locked saline lake in the desert.

On approaching the high desert in San Felipe Valley, we first encounter a special kind of chaparral, dominated by a type of bushy juniper tree (Figure 33).

Figure 33. Juniper-rich chaparral in western San Felipe Valley (Volcan Mountain in the background).

Farther to the east, we notice a strong showing of desert plants within the changing chaparral: abundant Creosote Bush and various types of cactus, foremost a nasty-looking Cholla cactus (*Cylindropuntia* sp.). We are looking at a Creosote-dominated chaparral (Figure34). The Creosote Bush (*Larrea tridentata*) becomes increasingly abundant, relative to other plants, as the desert becomes more typical. It is one of the most common and characteristic desert shrubs, from the Mojave Desert north of here to the deserts of northern Mexico and into Baja California to the south (Marshall, 1995; Rebman and Roberts, 2012). It has ill-smelling resin, which is also ill-tasting to herbivores, thus providing for chemical defense. It is long-lived, cloning itself for thousands of years in places. The plant is (and has been) well-known as a treasure chest for medicines for all sorts of ailments.

Figure 34. Creosote Bushes in San Felipe Valley east of Volcan Mountain. Left: Creosote-dominated chaparral with Cholla. Right: close-up of the typical desert plant, in San Felipe Valley, along Route 78, in the eastern part of the valley, before reaching Scissor's Crossing.

Yucca is strongly represented also in San Felipe Valley along Highway 78, with two types, the "Lord's Candle" and the "Mohave Yucca" (Figure 35). The latter grows a stout tree-like trunk and commonly has more than one cluster of flowers on top.

Figure 35. Two types of Yucca: the Lord's Candle (two panels to the left) and the Mohave Yucca (right.)

The common occurrence of Yucca here in the high desert flags this plant as desert-adapted. This should be kept in mind when seeing representatives in the Coastal Sage Scrub and in dry places all through the chaparral on the western slopes. Yucca plants are members of the agave family, which has many representatives in San Diego County and also in the southwestern dryland regions of the USA in general and in northern Mexico and Baja California (Figure 36).

Figure 36. Agave with a beginning bloom stalk, in the high desert of San Diego County near Sentenac Canyon.

The most convincing sign that we are indeed in a desert in eastern San Felipe Valley is delivered by the cactus plants and thickets within the local chaparral (Figure 37).

Figure 37. Cholla species (Cylindropuntia spp.) are abundant among the cactus plants in San Felipe Valley. (The photos were taken before the Pine Fire.)

The place to look for the desert plants is upslope from Highway S2 near Scissor's Crossing, on the side away from the San Felipe Creek (which has the usual riparian vegetation, with willows and Sycamore and Cottonwood trees). Cacti are abundant here. While it is true that even the coastal zone has cacti (especially the paddle-shaped *Opuntia littoralis*), the desert surely has the greater abundance of very well-armed Cholla species (*Cylindropuntia* spp.). On Highway S2 near Scissor's Crossing we are in a Wildlife Area of the State of California (Fish and Wildlife Department), which recently acquired the Valley. Geographically, we are in the transition zone between Volcan Mountain to the west and the Colorado Desert to the east. But the rain shadow helps to make this valley part of the desert country, on balance, which is very apparent on the eastern side of the valley.

Across the valley, looking west from S2 toward Volcan Mountain, we can see a rather dense plant cover and dark green chaparral. We can also see that an ancient valley appears well above the present one, with a distinct terrace denoting the former valley floor (Figure 38). Uplift combined with down-cutting by erosion within the valley center is indicated. The lowermost terrace ends at the creek with its riparian vegetation, making a cliff. Leafless cottonwood is the most conspicuous tree in the photo, which was taken in winter, well before the great "Pine Fire" (2002) struck here.

Figure 38. Evidence that the San Felipe Valley is subject to uplift and to climate change.

Traveling northward along S2, what is most striking is the difference in plant cover to the east of the road, toward the desert, and to the west of the road, toward the valley bottom with its riparian plants. Both areas were ravaged by fire years ago, but plants on the valley side have largely recovered, while a considerable proportion of the ones on the desert side have not. As a consequence, the desert side of the valley looks truly desolate (Figure 39).

Figure 39. The eastern (desert) side of San Felipe Valley, along S2, has a sparse plant cover and many stark ruins of burned plants, barely recovered from a great fire.

The observed lack of recovery of plants on the eastern side of the valley is somewhat surprising in the case of mesquite plants that grow in the region. Mesquite plants have enormously long roots, reaching deep into groundwater levels where possible. Many geology textbooks show the "normal" groundwater level following the surficial topography, at some depth. If this were the case here, the differences between west and east along Route S2 would be difficult to explain. But this is the desert. What is manifestly important to the plants is the distance to the valley bottom; that is, to the water within the creek or below the creek bed. Any groundwater would be at or near the center of the valley.

Concerning the Mesquite, the species here dominant has willow-like catkins during the flowering season in May (Figure 40). It produces beans that are edible both by people and by cattle. The latter fact has an interesting corollary. Cattle spread undigested mesquite beans and, in places, thereby help the Mesquite to invade grasslands. There is no free lunch in ecology. Mesquite makes beans for a reason that makes sense for the Mesquite, and not just to feed herbivores (including cattle).

Figure 40. Flowering Mesquite along Highway S2, in May.

Among the Mesquite plants we see abundant Cholla cactus. During May, when it is flowering time, we also note the yellowish-green flowers that grace many of the tips of their cylindrical stems (Figure 41).

Figure 41. Flowering Cholla in San Felipe Valley, in May.

For cactus the same observation holds as for the Mesquite: good recovery to the west of the road, toward the valley bottom, and poor recovery on the nearly barren slopes on the eastern side.

Much of what we see in terms of landscapes in the lower desert east of San Felipe Valley (in the adjacent Anza-Borrego Desert State Park) reflects the geologic history of the Salton Sea and its response to being filled by the Colorado River or by incursions of the sea from the south. The Salton Trough itself is a rift produced by the enormous plate movements that also made the Sea of Cortez, starting in the late Miocene. Within the Anza-Borrego Park are hills made of uplifted and tilted sediments, testifying to the presence of the tectonic forces that shaped the landscape. The other important forces are those of erosion. Even in the desert, where water is definitely in short supply, much of the landscape shows the effects of enormously powerful floods. The floods carve canyons and make delta-like deposits at their exit to the desert floor. At those exits, the floods lose power because the water is no longer confined to a channel and can spread over large areas, greatly decreasing depth and velocity, and increasing friction with the ground. Floods are real. If you see dark rainclouds in the mountains to the west while being in a dry wash, get out of it and head for high ground. Fast.

The plant cover in the desert is much thinner than in the chaparral. There is commonly no problem moving among the well-spaced plants of the desert, although it is not recommended in view of the fragility of the organogenic crust that slowly forms on top of the soil and is easily destroyed. Typical desert plants are the Ocotillo and various species of Cholla cactus (Figures 42 and 43), as well as Creosote bush and Mohave Yucca. Cacti include Barrel cactus and Prickly Pear types (Figure 44). Similar plant associations (and others) may be seen in the deserts to the north (Mohave or Mojave), to the east (Colorado Desert), and to the south (Sonoran Desert and Baja California) of San Diego County.

Figure 42. Ocotillo, a common desert plant in San Diego County.

Figure 43. A "forest" of Cholla cactus in the desert.

Figure 44. Blooming cactuses (Ferocactus sp.*, Opuntia* sp.*) in the western rim of the Colorado desert, San Diego County.*

One of the ways to enjoy a rich sampling of desert botany is to take the Grapevine Canyon Road down into the high desert from Ranchita. A robust vehicle is of advantage – the Grapevine "Road" is a road in name only. There are definitely some rough spots on this trail.

Winter snow and acorns

Rainfall late in the winter season commonly is the most important source of water for the plant cover in all of San Diego County. However, the central mountains are high enough so winter precipitation can arrive as snow on occasion (Figures 45 and 46). Sometimes there is so much snow certain roads have to be closed. The presence of conifers is typical for areas that have snow in winter.

Figure 45. Winter scene along Highway 79 (Mt. Laguna), south of Julian.

Mount Laguna is known for its opportunities for winter sports (elevations exceed 6000 feet), for its astronomical observatory (operated by San Diego State University) and for its motel and lodge.

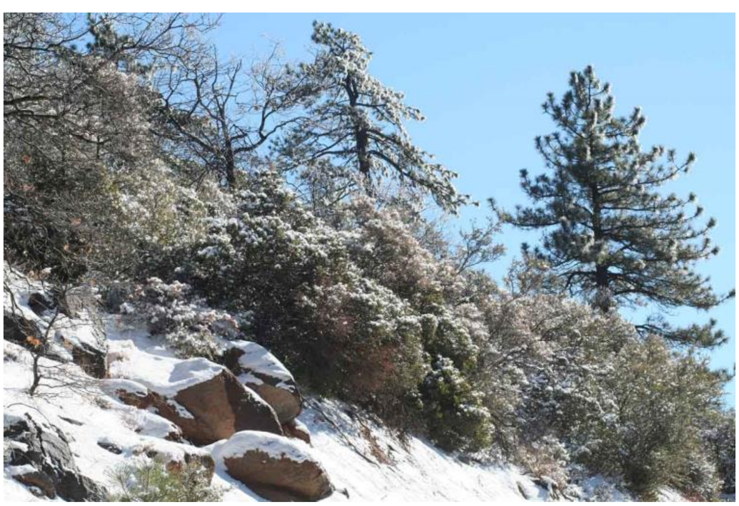

Figure 46. Winter scene along Route 79 (Mount Laguna, San Diego County).

Also, in the vicinity of Julian there are certain deciduous oaks (called "Black Oak"). These have large acorns in fall, acorns that used to be collected for food by the native people who lived here for centuries and millennia (Figure 47). The oaks were ground into a meal, from which the bitter tannin was readily removed. The meal was then available for making gruel and pancakes.

Figure 47. Acorns of a Black Oak in fall (near Julian) and a hole in granitic rock, presumably a receptacle for grinding acorns made a long time ago by tribal Americans.

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APPENDIX GEOLOGIC TIME SCALE

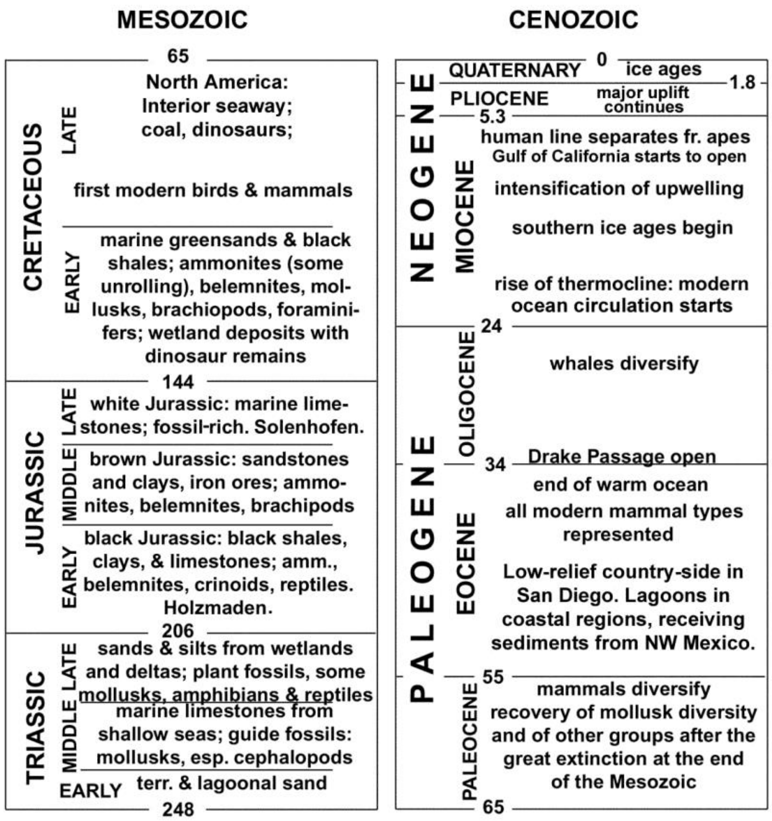

Figure A1. A geologist's time scale for the last 250 million years (Mesozoic and Cenozoic) – the time most relevant for the landscape evolution in San Diego County. All numbers denote ages in millions of years.(Checked against biostratigraphy in ODP reports.)