The Environmental and Cultural History
of the
North Fork Eel River Watershed and the Yolla Bolly Country

Chapter 1

Origins:
A Thumbnail History of the Geology and Soils of the Yolla Bolly Country

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Three Rivers, Ca.
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Preface

I first published my book: *Environmental History and Cultural Ecology of the North Fork of the Eel River Basin, California* in 1995. Since then, I have published numerous articles, presented professional papers, and compiled, organized, and catalogued the existing historical archival data on the North Fork Eel River watershed for future researchers (Keter: TCC: n.d.). Most of these earlier papers and publications can be found on my website: *solararch.org*. The Trinity County Historical Society in Weaverville has all the original homestead records and other historical documents referred to in this study.

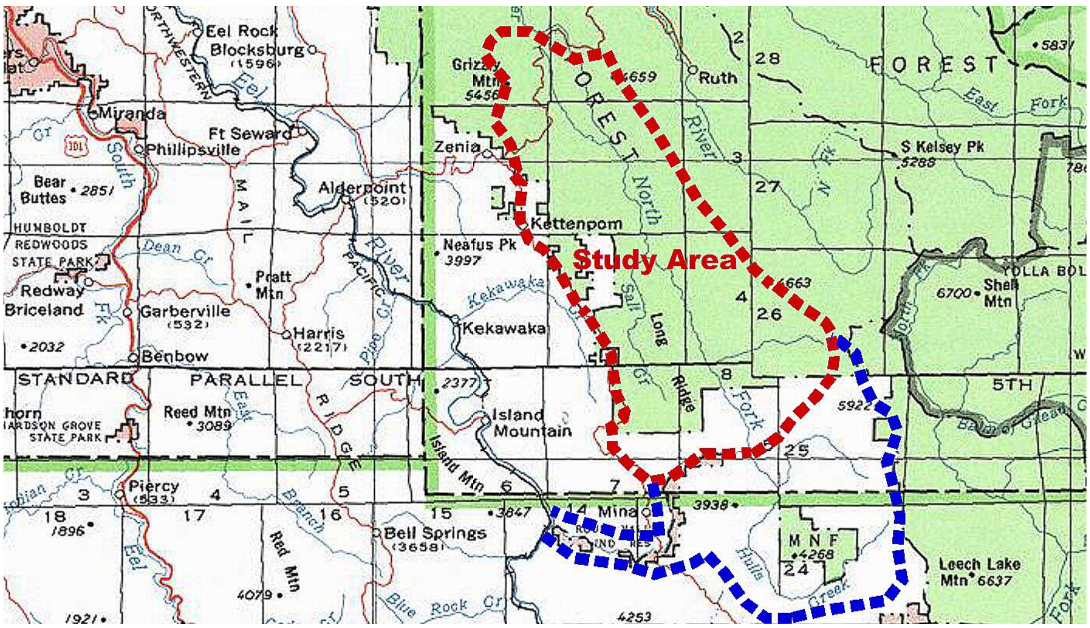
The goal of this series of papers documenting the natural and cultural history of the North Fork Eel River watershed and the surrounding Yolla Bolly country is to provide an updated overview of the region since my book was published. This includes field research, interviews with long-time residents, and archival research collected over the last several decades. I have also incorporated scientific environmental studies undertaken over the last two decades from numerous disciplines that have greatly contributed to our understanding of the region's natural history.

Chapter 1 presents a brief overview of the geologic "Origins" of the Yolla Bolly country and North Fork Eel River watershed. Future chapters will include synopses of the area's past climatic history, prehistory, ethnography, history, and an outline and discussion of the flora and fauna found in the region within in their historical and ecological contexts.

Introduction

The North Fork Eel River watershed is located roughly in the center of what is referred to as "Yolla Bolly country" by local residents and in the histories of this still remote region. The term Yolla Bolly comes from the Nomlaki Wintun language and roughly translates as "high snowy mountains." The Yolla Bolly country stretches north from Round Valley into southeastern Humboldt and southwestern Trinity Counties. It is a vast region of deep cut canyons and steep almost-never-level terrain. It includes the highest mountains in the Coastal Ranges of California, the Yolla Bolly Mountains with several peaks over 7,000' in elevation.

Most of the North Fork Eel River watershed is located within the borders of southwestern Trinity County. This study focuses on the region of the watershed north of Hulls Creek. The majority of the land within this portion of watershed (Map I-1 red dashed line) is publicly owned, and is managed by the Mad River Ranger District of the Six Rivers National Forest (Green shading on Map 1). This area was the focus of ongoing environmental studies by the author in the 1980s and 1990s (Keter 1995). The portion of the North Fork Eel River watershed below the mouth of Hulls Creek lies within Mendocino County. A large part of the watershed in this area (Map 1: blue dashed line) is owned by the Round Valley Indian Reservation and several private land holders. There are also a few tracts of public lands in the Hulls Creek watershed managed by the Bureau of Land Management and the Mendocino National Forest.



Map I-1

(CA Topo: 2000)

Origins:

Although the story of the Yolla Bolly country and North Fork Eel River watershed begins long before humans first entered the region, geologically speaking, its bedrock geology, like that of the rest of northwestern California, is relatively recent. As with much of the western portion of the state, northwestern California did not begin to exist as a recognizable terrain until about five million years ago. Prior to that, ongoing geologic processes including: plate tectonics, earthquakes, volcanism, weathering, erosion, and deposition, were forming the Earth's landscape.

Most of these processes took place gradually; spanning geologic eras of tens of millions of years. The Earth, at times, however, was also affected by catastrophic events--including a massive volcanic eruption event in Siberia about 540 million years ago that led to the mass extinction of plants and animals worldwide, and an asteroid striking the earth about 66.5 million years ago that marked the end of the Cretaceous Period, and the extinction of most of the species of animals inhabiting the earth at that time including dinosaurs.

Today, the geologic history of the Yolla Bolly country is expressed in its bedrock geology, soils, and the character of its topography and landscape. This geologic history, combined with the effects of weathering and time, measured in millions of years, all conspired to create the environmental conditions for the various species of plants and animals that were able to emigrate, adapt, and become established in this *Terra nova* after its birth about five million years ago.

Geology

The Precambrian 4.6 billon years ago to 541 Ma

The Precambrian covers the vast bulk of the Earth's geologic history, beginning with the planet's creation about 4.6 billion years ago, and ending about 541 Ma (million years ago) with the emergence of complex, multi-celled life-forms at the beginning of the Paleozoic Era. Geologists sometimes refer to the Precambrian as a Supereon because, more recently, it has been further subdivided into three eons; the Hadean, the Archean and the Proterozoic (Table 1-1).

Precambrian	
Hadean Eon	4.6 billion to 4.0 billion years ago
Archaean Eon	4.5 billion to 2.5 billion years ago
Proterozoic Eon	2.5 Billion to 541 million years ago
More recently, the Precambrian had been subdivided into three eons --the Archaean and Proterozoic Eons have been further subdivided into Eras.	

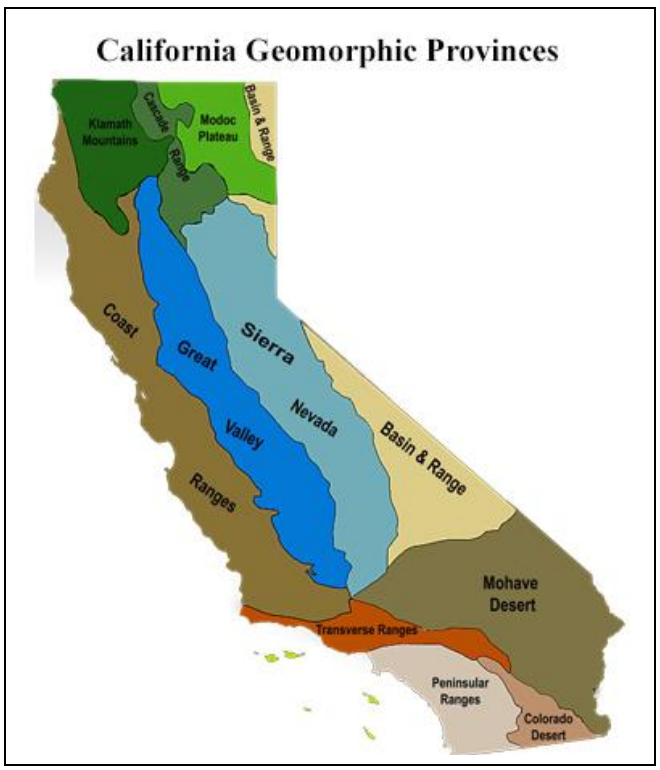
Table 1-1

The oldest known rocks on Earth are sandstone rocks from Western Australia containing 4.4-billion year old grains of the mineral zircon. The oldest known exposed bedrock is found on the Canadian Shield in the Nuvvuagittuq greenstone belt located on the eastern shore of Hudson Bay in northern Québec. These ancient rock outcrops have been dated to 4.3 billion years old. The Canadian Shield forms the original core (craton), of the North American continent and is the largest exposure of Precambrian-aged rock in the world. It is an accumulation of smaller plates and terranes (fragments of the Earth's crust) that formed between about 2.5 and 1.25 billion years ago, and includes portions of Greenland, the Laurentian Mountains of eastern Canada, the Adirondack Mountains of New York, and the Superior Upland region (northern Wisconsin, Minnesota, and Michigan) lying south and west of Lake Superior).

The Geology of California and the North Coast Ranges

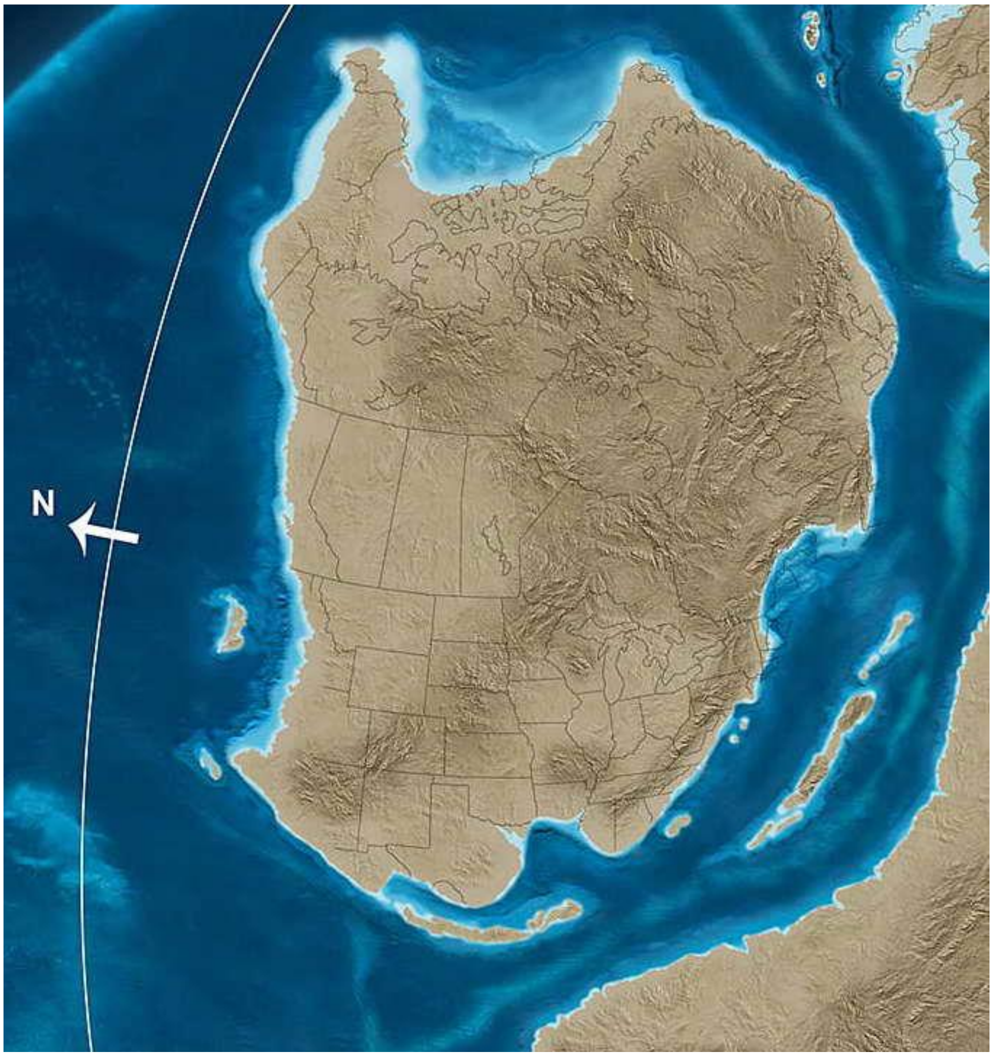
As compared to the ancient rock of the Canadian Shield, California's geologic history is much more recent, but very complex. The land that is now California came into existence as a result of plate tectonics and continental drift, and most of the state did not, in geologic terms, exist as a coherent fragment (terrain) of the earth's crust until relatively recently. Few rocks in the state are older than about 600 million years. The oldest rocks found in California are the metamorphosed basement rocks of the Mojave (Mojavia) Desert Geomorphic Province, encompassing most of the Mojave Desert, as well as portions of the Great Basin and parts of the Transverse Ranges (Map 1-1). They date to around 1.7 billion years. Basement rock is the thick foundation of the ancient and oldest decomposed metamorphic and igneous rocks that forms the crust of continental plates. These rocks were highly altered as the plates were compressed and stretched (metamorphosed); the most common rocks derived from this era are classified as gneiss and schist.

Gneiss is formed deep in the Earth by high-temperature and high-pressure metamorphic processes acting on formations composed of igneous or sedimentary rocks. Schist forms at much lower temperatures than gneiss, but from similar processes. Schist is formed from many different kinds of rocks, including sedimentary rocks such as mudstones, igneous rocks, and volcanic ash, and is common in the North Coast Ranges and the Yolla Bolly country (see for example South Fork Mountain schist).



Map 1-1
The Geomorphic Provinces of California
(H. Keter)

There are no known rocks in the Coast Ranges of California of any comparable age or origin to those of the Mojave Desert. Given the movement of earth's crust and entire land masses as a result of plate tectonics, in reality, there was no "there there," nor anything that we today could recognize as resembling the landscape and topography of what is now the state of California during the Precambrian--much of the time it lay at the bottom of an ocean (Map 1-2). The creation of California as a land mass would not take place for tens of millions more years.



Map 1-2
The Late Precambrian, 550 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

The Phanerozoic Eon: 541 Ma to the Present

The Phanerozoic Eon follows the Precambrian Supereon and covers the last 541 million years of the earth's geologic history (Table 1-2).

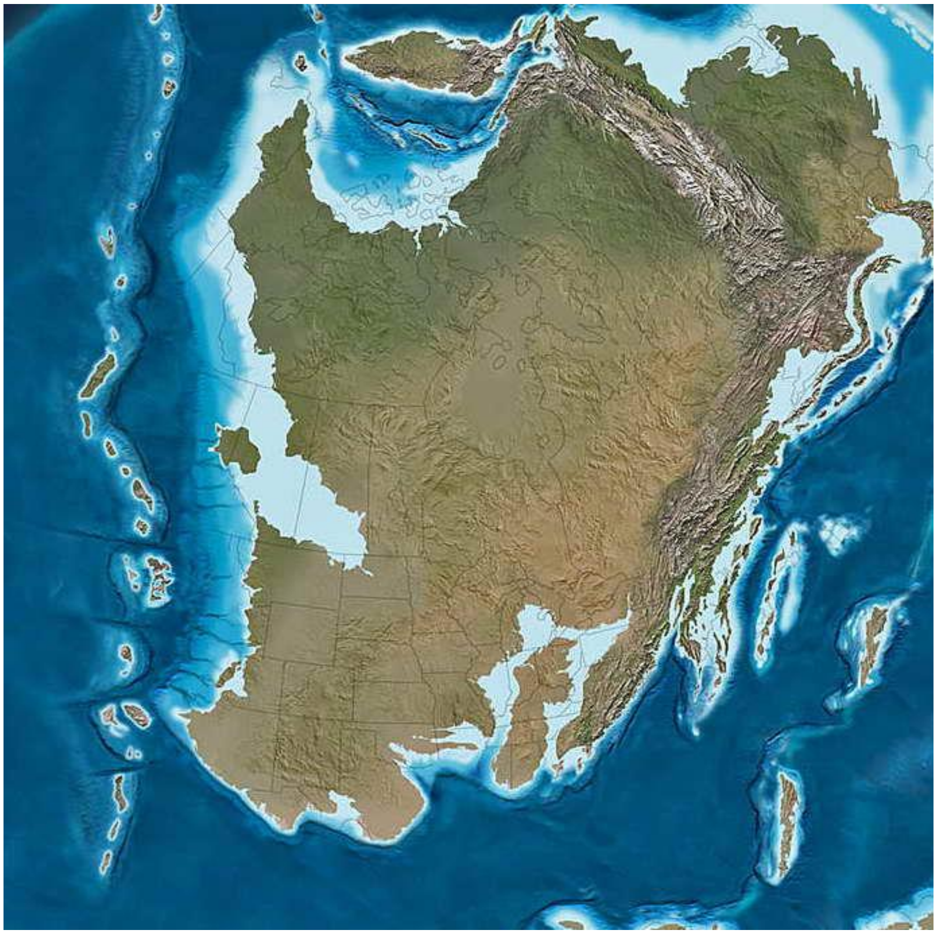
Cenozoic	Quaternary (Pleistocene/Holocene)	2.588–0
	Neogene (Miocene/Pliocene)	23.03–2.588
	Paleogene (Paleocene/Eocene/Oligocene)	66.0–23.03
Mesozoic	Cretaceous	145.5–66.0
	Jurassic	201.3–145.0
	Triassic	252.17–201.3
Paleozoic	Permian	298.9–252.17
	Carboniferous (Mississippian/Pennsylvanian)	358.9–298.9
	Devonian	419.2–358.9
	Silurian	443.4–419.2
	Ordovician	485.4–443.4
	Cambrian	541.0–485.4

Table 1-2

Paleozoic Era 541 Ma to 252 Ma

The beginning of the Cambrian Period 541 Ma marks an important turning point for life on earth. Prior to that time, with a few notable exceptions, most organisms were small in size and mostly unicellular. This rapid diversification of all life forms that produced the first ancestors (phyla) of all modern animals is known as the Cambrian Explosion. This is also about the time when some animals first developed hard shells that are, today, preserved in the fossil record and provide important clues and insights about life and the geological processes taking place during that era.

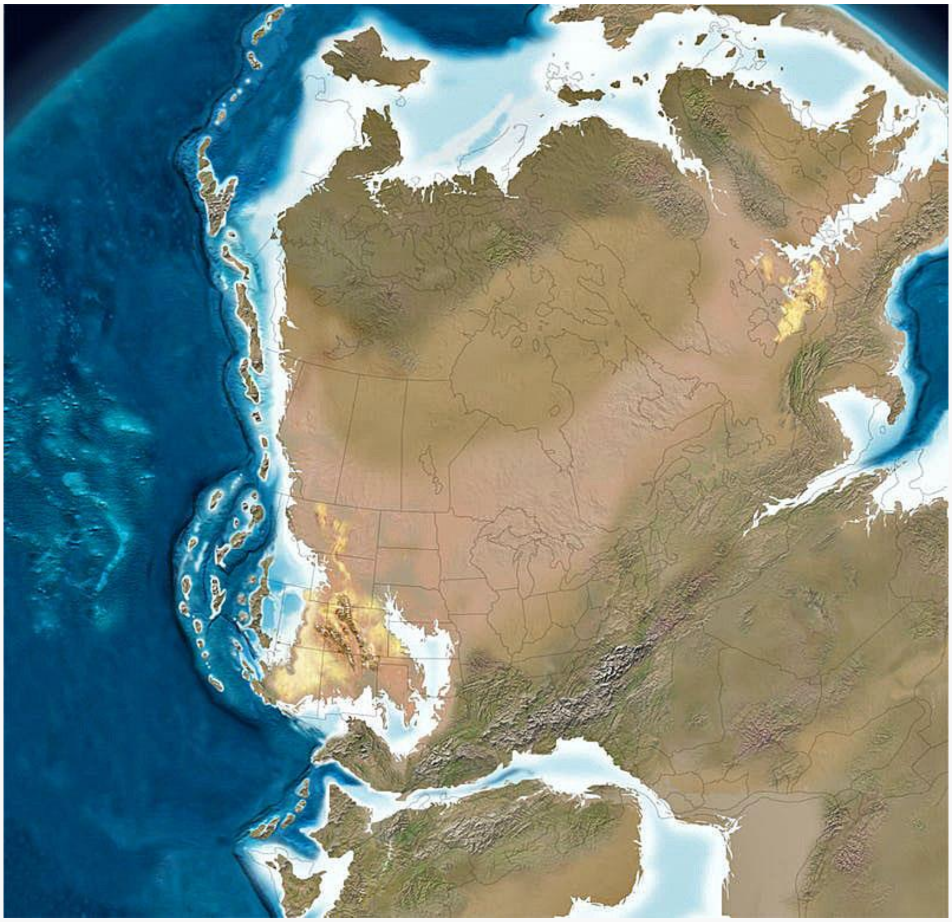
Between the late Precambrian, and the early Devonian Period (about 400 Ma), a span of nearly half a billion years, it was, geologically speaking, relatively quiet in what is now western North America. Much of California was still underwater, and the western coastline of what would become North America was located somewhere well to the east (Map 1-3).



Map 1-3
The early Devonian Period 400 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

Many of the rocks dating to this era in California consist of carbonates like limestone and dolomite. Limestone is a calcium carbonate mineral whereas dolomite is made of calcium magnesium carbonate. Sand, clay, and silt are commonly found in limestone as impurities, but they ae not quite as common in dolomite. The ancient bristlecone pines growing on dolomite parent soils at about 10,000 feet in the White Mountains provides evidence of the warm, shallow inland sea that once covered this region. The warm ocean temperatures, along with little incoming terrestrial sediments, were similar to the conditions found today in the Gulf of Mexico.

Over the next 130 million years tectonic plate movements and continental drift began to cause subduction to the west of the North American margin, and by the middle of the Permian Period, about 275 Ma, all of the (existing) continental plates had joined to form the super continent of Pangea (Map 1-4).



Map 1-4
Middle Permian, 275 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

Mesozoic Era 252 to 66.5 Ma

By the beginning of the Mesozoic Era about 252 million years ago an extensive volcanic-arc system began to develop along the western margin of what was then the North American continent. At about the same time, the land mass of Pangea began to separate forming a number of plates that would eventually make up the Earth's continental land masses as they exist today. During most of the Mesozoic Era much of what is now western California remained underwater.

The Mesozoic Era is sometimes called the Age of Reptiles due to their dominance on the planet at that time. There was also a rapid growth in new species of conifers and ferns. The climate of the Mesozoic alternated between warming and cooling periods. Overall, however, the Earth was hotter than it is today.

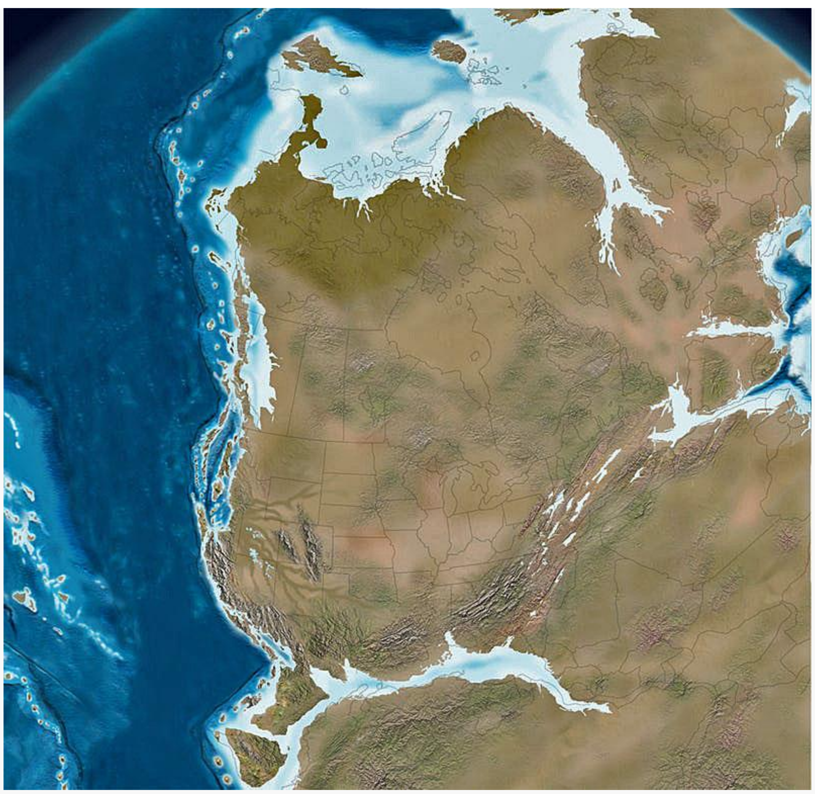
Mesozoic Era (252 to 66.5 Ma)	
Triassic Period:	252 to 201 Ma
Jurassic Period:	201 to 145 Ma
Cretaceous Period:	145 to 66.5 Ma

Table 1-3

Triassic Period 252 to 201 Ma

The Triassic was a hotter and drier period with no evidence of glaciation and the polar regions were generally temperate with a climate suitable for the growth of forests and the presence of vertebrate animals. It was during the early Triassic Period that reptiles first begin to appear in the paleontological record. The late Triassic marked the first appearance of dinosaurs that came to dominate the Earth during the Jurassic Period. It also marked the first appearance of mammals about 210 Ma. The first mammals were tiny, fur-bearing shrew-like animals whose ancestors are referred to as "proto mammals"--small mammal-like reptiles.

The rock formations from the Triassic in western North America are for the most part marine shale and limestone with igneous intrusions. California was still submerged and the ocean extended to the west from about present day Colorado and Wyoming (Map 1-5).



Map 1-5
Late Triassic, 210 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

Jurassic Period 201 to 145 Ma

The Jurassic Period is known as the "Age of Dinosaurs." During this period, birds also began to evolve into their modem day forms from a small, specialized group (clad) of dinosaurs classified as theropods, characterized by hollow bones and three-toed limbs. The oceans were inhabited and dominated by many species of reptiles, while pterosaurs were the first animals to take flight.

The oldest Pacific Ocean floor began forming during the mid-Jurassic Period about 180 Ma. Then, towards the end of the Jurassic Period about 150 Ma, Pangea began to break apart. At that time, far western California (Map 1-6) was still submerged beneath the waters of an ancient ocean (it is referred to as the Panthalassa Ocean and surrounded the supercontinent of Pangaea). The Nevadan Mountains now formed the western coast of North America, and the sea never again extended farther east than the eastern edge of what is now the Central Valley of California. At about the same time, uplifting granitic rock was starting to create the Peninsular Range (Map 1-1) of Southern California.

Map 1-6
Late Jurassic 150 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

Cretaceous Period: 145 to 66.5 Ma

The Cretaceous Period is the longest period of the Mesozoic Era. It is the link between the ancient life-forms of the Triassic and Jurassic Periods, and the plants and animals that dominate the Earth today. The North American land mass had already begun pulling away from Eurasia during the Jurassic, and by the early Cretaceous Period, Pangea had essentially split into two continents, as segments of both Laurasia in the north, and Gondwana in the south began to drift (rift) further apart (Map 1-7). At about the same time on the southern continent of Gondwana, South America had started to split off from Africa, and the continents of India, Australia, and Antarctica were beginning to separate.

Map 1-7
Early Cretaceous Period 140 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

The earliest granite of the Sierra Nevada Mountain Range started to form during the Cretaceous Period. As the Farallon Plate to the west of California began to drift eastward, it began to subduct beneath the North American Plate. This movement resulted in magma forming deep within the Earth. Over time, the central part of the Farallon Plate was completely subducted beneath the southwestern part of the North American Plate forming granitic plutons. Plutons are gigantic granitic (balloon-like) bodies of igneous rock that are formed from heat and pressure along the base of continents as the result of plate movement. As they are uplifted, plutons solidify when they cool near the surface.

Plutons dating to about 115 Ma to 87 Ma combined to begin forming what would become the 400 mile long Sierra Nevada batholith. Batholiths are formed when many plutons converge to form a huge expanse of granitic rock. The batholith parallels the subduction zones to the west and is composed of numerous plutons that had converged to form the earlier Nevadan Mountain Range.

The Sierra Nevada Mountains we see today are, therefore, related to the Nevada Mountain Range, but were formed much later (see below). During this era sedimentary deposits from erosion and weathering coming to the west from the Nevada Mountain Range were accumulating off the coastal plain on the continental shelf and in the offshore subduction zone (Map 1-8).

Map 1-8
Mid Cretaceous, 100 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

By about 76 Ma in what was to become the North American continent a large sea separated the land masses of Laramidia and Appalachia, and most of what is now California west of the Nevadan Mountains still remained underwater (Map 1-9). The oceanic crustal material was then, over millions of years, thrust up against the Sierran block--slowly extending the boundary of the North American plate further west.

Map 1-9
76 Ma much of California remained underwater
(Maps: Ron Blakey, Northern Arizona University n,d,)

Geological evidence of this era can be found today in the high Sierra Nevada where some of the rocks overlie and predate the creation of the batholith. Among the most interesting are "roof pendants" consisting of sedimentary and metamorphic rock deposits overlying the batholith that date to the Paleozoic Era. In the southern Sierra Nevada on west facing slopes, some of these roof pendants contain stands of sequoia trees (see for example the Giant Forest, Sequoia National Park) that cannot grow on the thin granite soils that underlie most of the batholith.

At about this time, the subduction zone shifted west to about the current location of the Coast Ranges (Image 1-1). The mix of rock from the upper mantle and sedimentary deposits from the eroding terrain to the east continued accumulating on the continental shelf and in the offshore subduction zone. Today this complex mélange underlies much of the Central and North Coast Ranges and is referred to as the Franciscan Formation.

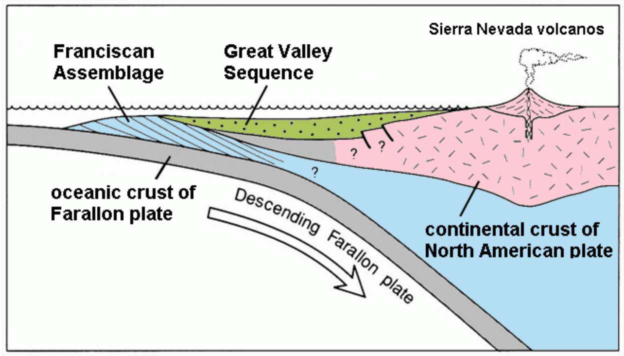


Image 1-1
(Image: Free use Wiki Commons)

The Cretaceous Period ended about 66.5 Ma when an asteroid struck resulting in one of the greatest mass extinctions in the history of the Earth; exterminating the dinosaurs, marine and flying reptiles, and many marine invertebrates. Some species of smaller terrestrial animals including, insects, turtles, lizards, and birds survived. The mass extinction also resulted in the loss of numerous species of mammals. Those that survived were therians (placental animals producing live births) and are the ancestors of all living species of mammals. Although much of western California still remained under water (Map 1-10), by end of the Cretaceous Period the inland sea between Laramidia and Appalachia began to close and the present-day continents were becoming separated from each other by expanses of water like the North and South Atlantic Oceans.

Map 1-10
Cretaceous-Tertiary, 65 million years ago
(Maps: Ron Blakey, Northern Arizona University n,d,)

Although most rocks and sediments found in the Franciscan Formation underlying the North Coast Ranges date to the Cretaceous Period, as noted earlier, some rocks and rock outcrops date to as early as the Jurassic Period. The Coast Ranges have continued to be subjected to tectonic forces and the heavily folded and faulted topography of the Yolla Bolly country reflects this geologic history, with the weathering of the more easily erodible sedimentary deposits resulting in the landscape that we see today.

The Cenozoic Era 66.5 Ma to the present

The Cenozoic Era spans the last 66.5 million years of the Earth's history, from the end of the Cretaceous Period of the Mesozoic Era to the present. It is characterized by a generally cooling and drying climate, the current configuration of continents, and the emergence and dominance of mammals, birds and flowering plants.

Cenozoic Era	
Paleogene Period*	66.5 to 23 Ma (subdivided into three epochs)
Paleocene Epoch	66.5 to 55.8 Ma
Eocene Epoch	55.8 to 33.9 Ma
Oligocene Epoch	33.9 to 23.03 Ma
Neogene Period*	23 to 2.5 Ma (subdivided into two epochs)
Miocene Epoch	23.03 to 5.332 Ma
Pliocene Epoch	5.332 to 2.58 Ma
Quaternary Period	2.5 Ma (subdivided into two epochs)
Pleistocene Epoch	2.58 Ma to 11,700 BP
Holocene Epoch	11,700 BP to present

*Paleogene and Neogene are relatively new terms that have replaced the Tertiary Period.

Table 1-4

Paleogneic Period 66.5 to 23 Ma

By about 50 Ma Laramidia and Appalachia had joined together forming the Great Basin and Colorado Plateau. While most of what is now California remained underwater, the ancestral Nevadan Mountains had eroded down to relatively low-lying hills (Map 1-11).

Map 1-11
Paleogene Period--Eocene Epoch, 50 million years ago
(Maps: Ron Blakey, Northern Arizona University n,d,)

Over the next 10 million years large rivers flowed west from the eroding hills and mountains; depositing gravels rich in gold in what would become the foothills of the Sierra Nevada Mountains. This erosion and deposition continued without interruption until around 40 Ma. At about that time, the coastline began to shift back and forth (depending on rises and falls in sea level) producing a patchwork of marine and non-marine sedimentary rocks in the regions that were to become the Coast Ranges and the western Transverse Ranges.

Then, about 25-29 Ma, the Farallon oceanic plate that had been subducting beneath the western edge of the North American Plate, was completely overridden, and the North American and Pacific plates came into direct contact for the first time. As a result, the San Andreas Fault system was formed. In northwestern California and in the Pacific Northwest--the triple junction plate (where the Gorda Plate, the North American Plate, and the Pacific Plate meet) was also formed at this time. Today movement continues along both of these faults.

Neogene Period 23 to 2.5 Ma

About 20 million years ago, during the Miocene Epoch, the shoreline topography of California began to change significantly as mountain ranges began to rise along the coastline, uplifting and exposing marine sedimentary deposits (Franciscan Formation) that had accumulated in offshore continental shelf and marine basin environments. These sediments, as noted earlier, were derived from past erosion of the continental land mass and from organic remains deposited in the sea (Map 1-12).

Map 1-12
Neogene Period--Miocene Epoch, 15 million years ago
(Maps: Ron Blakey, Northern Arizona University n,d,)

It was only about 10 Ma that the Sierra Nevada Mountains batholith started to form when the SVGV (Sierra Nevada-Great Valley) block of terrain started to uplift and tilt to the west as a result of extensive volcanic activity in the Great Basin. This geologic activity thinned the eastern portion of the SVGV (essentially the eastern portion Sierra Nevada batholith) making it more buoyant then the region to the west. As a result of this uplift in the east, the block began to rise and to tilt (like a table being lifted up on one side) to the west (Image 1-2).

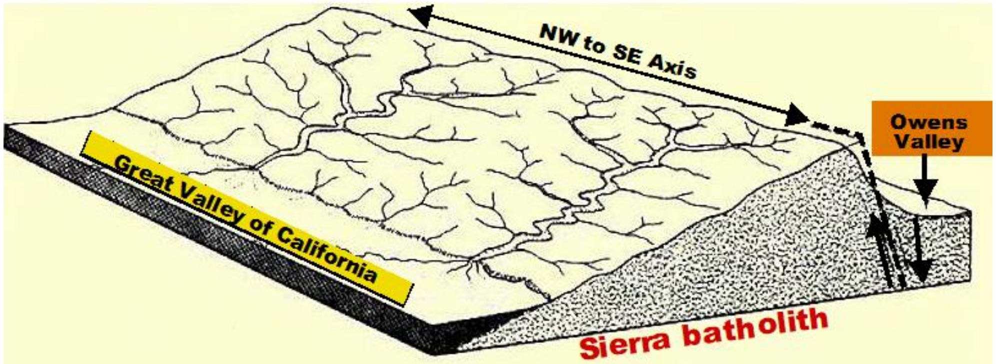


Image 1-2
About 10 Ma the Sierra batholith began uplifting along its eastern margin
T. Keter

The Great Valley of today began to form an inland sea by about 8 Ma as the Coast Ranges began to uplift as a result of continued plate movement (Map 1-13). A Mediterranean climate pattern appears to have evolved in California between about 7 Ma to 4 Ma as the California Current strengthened, although some regions to the south retained a pattern of summer precipitation. It was during this era that many of the trees and other species of vegetation found today in California migrated into the region and became established (see Chapter 2 on climate).

Map 1-13
Neogene Miocene, 8 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

About 5 Ma, mountain-building activity resulting from tectonic forces and faulting accelerated rapidly (in geologic time) throughout much of California. This seismic activity resulted in the uplifting of many of the mountain ranges in California that we see today: including the Sierra Nevada, the Coast Ranges, the Transverse Ranges, and the Peninsular Ranges (Map 1-1). By 3 Ma the uplifting of the Coast Ranges had resulted in the Great Valley being totally cut off from the Pacific Ocean except at the Golden Gate opening into San Francisco Bay (Map 1-14). It was at this time and extending throughout the entire Pleistocene that climatic cycles associated with the ice age began to affect much of the North American continent including coastal California.

Map 1-14
Neogene Pliocene, 3 Ma
(Maps: Ron Blakey, Northern Arizona University n,d,)

Quaternary Period 2.58 Ma to the Present

The Quaternary Period is the third and last period of the Cenozoic Era. It began only 2.58 Ma and is less than 0.1% of all of geologic time. The Quaternary Period is famous for its many cycles of glacial growth and retreat, the extinction of many species of large mammals and birds, and the emergence of *Homo sapiens*. The Quaternary Period is divided into two epochs the Pleistocene and Holocene.

Pleistocene Epoch 2.58 Ma to 11,700 BP

The Pleistocene Epoch spans the earth's most recent period of repeated glaciations separated by warmer interglacial periods; the sea level rising and falling with each cycle. During glacial periods, glaciers locked up much of the water from the oceans, lowering sea levels by as much as 400 feet, while streams cut deep into the Franciscan Formation forming the coastal valleys (like the Eel River Valley), and the steep-walled canyons of the North and South Coast Ranges. During interglacial periods, as the glaciers melted and temperatures warmed, the coastal valleys and river deltas became flooded--back-filling with sediments from the easily erodible sedimentary rock of the Franciscan Formation. Towards the end of the Pleistocene, by about 126,000 BP, the Great Valley was becoming a relatively level flood plain and was no longer an extension of San Francisco Bay. Although a few isolated bodies of water like Tulare Lake remained (Map 1-15).

During the last ice age, the Wisconsin, that ended about 15,000 years ago, sea level was as much as 350 to 400 feet lower than present day levels along the coastal margins of California.

Map 1-15
Quaternary Glacial Period 126,000 years ago
(Maps: Ron Blakey, Northern Arizona University n,d,)

Along with the rise of the sea level since the final retreat of the glaciers at the end of the Ice Age, tectonic forces (faulting, folding. and uplifting), erosion, and weathering have continued to shape the landscape and topography of the Coast Ranges and the Yolla Bolly country.

Holocene: 11,500 BP to the Present

By the beginning of the Holocene, as the climate began to warm, the stage was set for the migration of the first humans into northwestern California and the Yolla Bolly country. Although the geological processes of plate tectonics, seismic events, weathering, erosion, and deposition have continued since the first people settled to this region, this is but an instant on the geological time scale, and the topography of the Yolla Bolly country at the beginning of the Holocene would likely be recognizable to a modern day observer.

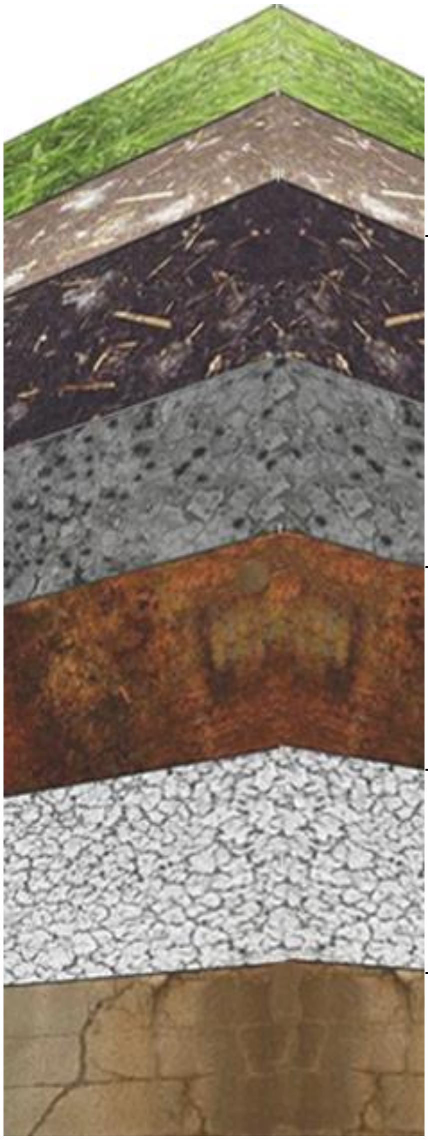
The Franciscan Formation and the Soils of the Yolla Bolly Country

Today, as noted in the section on geology, much of northwestern California--including the Yolla Bolly country--is underlain by the Franciscan Formation created between about 153 Ma to 66.5 Ma during the late Jurassic and Cretaceous Periods. The Franciscan Formation is sometimes referred to as an "assemblage" or "mélange" and can be up to 15,000 feet thick in places. It provided the parent materials for the formation of the soils that are found in the Yolla Bolly country. The Franciscan Formation is composed primarily of greywacke, sandstones, shales, and sedimentary conglomerates. Other kinds of rocks that can be found within the Franciscan Formation include chert, basalt (rare), and limestone. These more exotic types of rocks often predate the Jurassic Period and are remnants of earlier tectonic and geological activity (erosion, weathering, etc.) long before the region was uplifted. They are usually found in distinct outcrops or deposits. For example, outcrops of chert (some of the higher quality cherts were used for tools and projectile points), serpentinite, and blueschist (often decomposing to blue clays) are found throughout the Yolla Bolly country.

The USDA Natural Resources Conservation Service (web site) has provided the following definition for soil.

> Soil consists of horizons [layers of mineral soils] near the Earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity.

Table 1 provides a generalized description of each soil layer or horizon as classified by soil scientists.



Organic —leaves, twigs (recognizable) Organic — leaves, twigs (unrecognizable)	**Litter Zone**	**Organic Horizon** **O - Horizon**
Mineral/Humus Mix Dark coloration Maximum leaching of minerals and presence of clays	**Top Soil**	**A - Horizon**
Redisposition of clay and minerals	**Sub Soil**	**B - Horizon**
Relatively unweathered with the accumulation of calcium & magnesium carbonates. This layer lacks organic material	**Rock frag-ments**	**C - Horizon**
Solid Rock unweathered	**Bed Rock**	**R - Horizon**

Table 1-5
A generic view of soil horizons
(H. Keter; adapted from the web site: geologylearn)

Soil Formation

Before discussing the soils of the Yolla Bolly country it is important to first understand how soil is created. Soil formation involves a mix of four things: rocks and minerals, organic matter, water, and air (oxygen) that combine to form a matrix that can support the growth of certain species of plants and other organisms, while limiting others due to the presence or lack of certain minerals and nutrients in the soil.

Rocks and Minerals

Rocks and minerals are that part of the soil derived from the parent materials contained in the underlying bedrock. In general they make up about 45% to 49% of soil content, Soil is the same chemically and structurally as the underlying bedrock, but has been ground by erosional forces (for example; rainfall, floods, glaciers, wind, seismic activity, biological processes), that breaks down the bedrock into smaller particles. The sizes of the particles derived from the breakdown of the parent bedrock define soil texture and permeability. Smaller particles of rock are classified as clay, silt, and sand. Sand is the coarsest (largest in size and most permeable) while clays (that are commonly found in the Franciscan Formation) with the finest texture can be 1,000 times smaller than large sand particles.

Organic Matter

In general, about five percent of soils consist of living and dead animal and plant material in various cycles of growth and decay. Live organic matter found in soil can include earthworms, insects, microorganisms, and plant roots that help to loosen the soil and perform a valuable service for small animals by creating tunnels for air and water to flow through the soil. These organisms and their waste and decay all combine to create a microscopic world for bacteria, fungi, and algae that are important factors in the decomposition of organic matter. They also contribute to the chemical reactions that break down rock that enables plants to absorb minerals and other soil nutrients.

The actual percentage of organic matter content in a particular soil is based on the size and texture of the materials derived from the parent rock. For example, in the Yolla Bolly country, given the dominance of more fine grained closely compacted sedimentary oceanic deposits of the Franciscan Formation, the percentage of organic matter content in soil is significantly less than in other areas with rich loam soils.

Water

On average soil water content is about 25% for more mesic locations (see the Hydrology section for more on this topic). Water helps to dissolve the minerals that are found in the parent materials of the Franciscan Formation and that are needed for plant and animal growth. Water below the surface tends to move from smaller spaces to larger ones (downward through gravity and laterally through capillary action). Plants (through root systems, leaf cover, and shade) and animal activities (digging, borrowing, and homes of small subterranean animals), as well as biological and chemical processes related to root growth and decay, all contribute to determining the amount of water a soil can hold.

Soils heavy in clays, as is the case throughout large portions of the Yolla Bolly country, tend to absorb less precipitation, but can saturate--depending on the amount and length of time that a rain event occurs. It takes longer to saturate the tightly packed clay soils, but once they become saturated they tend to have stability problems on steep slopes. One of the most common reasons for slides in the Franciscan Formation is the result of saturated soils resting on steep unstable slopes of greywacke or sandstone (see Images 1-3 to 1-5).

Air

In general the air contained in soils makes up about 25% of its content. The oxygen that reaches the plant roots is vital to their growth. Soils with a loose texture and large pores (for example, sandy areas or soils with a high content of organic matter) permit higher air content than tightly packed clay soils.

Soils of the Yolla Bolly Country

Along with the four basic constituents that make up soil, there are a number of other things that help to define soil type at a particular site. They include natural historical processes related to erosion, as well as exposure, slope, and aspect. Climate provides the mix of heat, light, and moisture that further drives soil development. Additional variables affecting the composition, stability, and depth of soils includes natural events like wildfires, floods and earthquakes, ground disturbing activities by animals (bio-turbidity), and human land-use activities.

Vegetation is also an important factor contributing to the formation of and productivity of soil. For example, in a study by the USDA Natural Resources Conservation Service (Web site), they found that the soils formed under grassland vegetation contained:

> ...organic matter levels at least twice as high as those formed under forests because organic material is added to topsoil from both top growth and roots that die back every year. Soils formed under forests usually have comparably low organic-matter levels because of two main factors listed below: 1. Trees produce a much smaller root mass per acre than grass plants, and 2. Trees do not die back annually and decompose every year. Instead, much of the organic material in a forest is tied up in the tree's wood rather than being returned to the soil annually.

In effect, all of the variables cited above combine to produce soil color and texture. Soil color and texture vary widely across the Yolla Bolly country, and there are dozens of soil types in the North Fork Eel watershed; as documented by Six Rivers National Forest Soil Survey Report (see the web References Cited section for a link for a link to a pdf of the report).

Soil movement and the instability of the easily erodible sedimentary bedrock is a characteristic of the Franciscan Formation. Landslides include earthflows (Image 1-3), debris slides and flows (Image 1-4), and most common in the Yolla Bolly country--translational and rotational slides (Image 1-5).

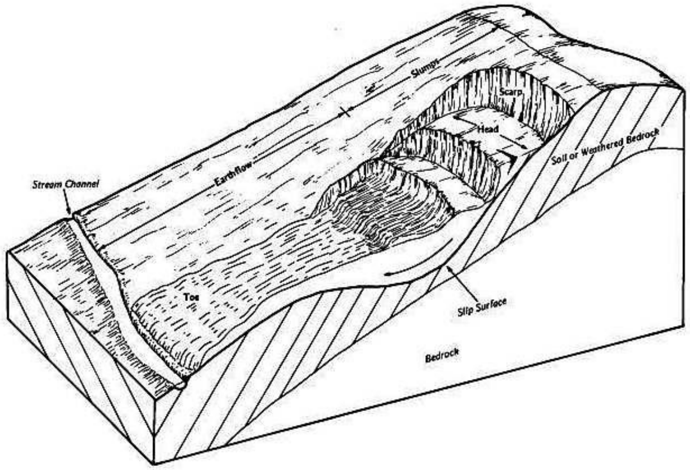


Image 1-3
Slump pattern of an earthflow in the clay soils of the Franciscan Formation
(Web site: USDA Soil conservation Service 1991)

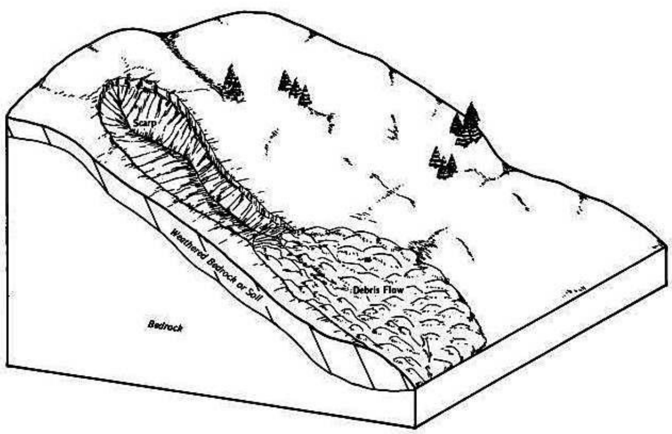


Image 1-4
Pattern of a debris flow in the clay soils of the Franciscan formation
(Web site: USDA Soil conservation Service 1991)

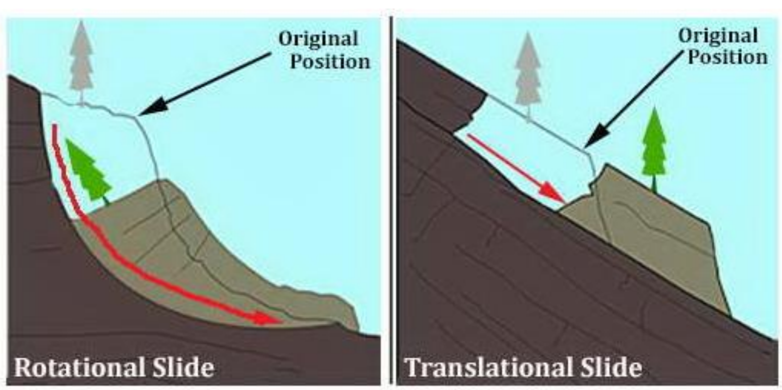


Image 1-5
(H. Keter adapted from the Web site: Eschool Today)

The movement of soil in the Yolla Bolly country is generally the result of an extended rain event that saturates the ground--often in areas that have been recently disturbed--for example, as a result of wildfires or human land-use activities. Landslides are complex in both their formation and their movement and are often hard to predict with any certainty. They result from two types of earth movement. Dormant slides are usually episodic or slow moving (over decades or centuries) and they often show little evidence of recent movement. Dormant slides have been caused by weathering and erosion, but vegetation has often been reestablished. They are usually triggered by extended rain events (for example, 25 year or 50 year flooding events) over-saturating the clay soils and causing extensive erosion from runoff. Active slides are presently moving or have recently moved. Active transitional and rotational slides are usually evident due to the presence of distinct topographic features including sharp barren scarps, cracks in the ground, and lack of vegetation, or trees with bent trunks, or growing at an angle due to earth movement.

Soils found in the Yolla Bolly country are generally permeable and more stable on slopes less than 30° (Lisle n.d. web site). Disturbance or the loss of ground cover can greatly accelerate surface and mass sheet erosion (loss of A Horizon soils) in both stable and unstable areas. Flood events like the 1955 and 1964 floods have also been major factors in the loss of soil, and erosion of the underlying bedrock where it is exposed. However, the most destructive effects to the soils and the loss of significant amounts of soil in the Yolla Bolly country have taken place since the beginning of the historic period. This loss is primarily the result of overgrazing by sheep and cattle during the late 19th and early 20th centuries (Image 1-6); the rooting of wild pigs that at one time numbered in the hundreds, possibly thousands; as well as homesteading activities, logging, and road building. Refer to Chapter 4 for an overview of land-use activities and their effects to the environment during the historic period (see also Keter 1994a).

Image 1-6
1919: Loss of top soil (A horizon) from sheep overgrazing
California (now Mendocino) National Forest

Both the natural processes related to erosion and deposition and the cumulative effects land-use activities during the of historic period have conspired to cause a significant loss of soils and increased sediment loads in the North Fork Eel River and its tributaries. For example, one study of erosion within the Eel River basin undertaken in the early 1970s (Anderson 1970: in Lisle n.d. web site) estimated that intensive timber harvesting and associated road building from about 1950 to 1975 had increased sediment loads within the watershed by several fold.

The effects to both the aquatic and terrestrial ecosystems due to erosion and loss of soil during the historic period are discussed in the sections of this study on hydrology and the environment. For a more in-depth overview on the dozens of soil types that are found within the North Fork Eel River watershed and their properties, see the Six Rivers National Forest Soils Survey Report (see References Cited for the pdf link to the web link).

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https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/california/sixriversNFCA1993/sixriversNFCA1993_1.pdf

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https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054253#designations

Images

Images 1-3 and 1-4

USDA Soil Conservation Service, 1991. Web site.
https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/california/mendocinotrinityCA1991/mendocinotrinityCA1991.pdf

Image 1-5
Web site : Eschool Today n.d. This image appears on numerous web sites.
http://igcseandalevelgeography.blogspot.com/2013/08/as-slides.html

Maps 1-2--to 1-13

Dr. Ron Blakey, Professor Emeritus of Geology at Northern Arizona University, recently published maps showing the step-by-step evolution of the tectonic plates comprising North America, from the Precambrian-era 550 million years ago to the present. Numerous web sites use these maps.
https://www.businessinsider.com/maps-of-north-american-continent-2012-7#middle-cambrian-510-million-years-ago-2

Table 1-5 Soil Profile
https://geologylearn.blogspot.com/2015/07/soil-profiles-and-soil-properties.html