Napa Valley:
180 million years to create

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Napa County's 813,000 acres of land and water consist mostly of mountain ridges and narrow valleys stretching on a north-south axis. Within Napa County there is an unusually wide variety of wildlife habitats and types of land:

Forests of mixed evergreens, woodland, grass and grazing lands, chaparral, agricultural land, lakes, bays and reservoirs, grasslands, coastal forest and marshlands.

These types of land and habitats are created by a combination of geology, climate and land use.

Geology

All of Napa County and the surrounding region is underlaid with sedimentary rock formation. This rock was formed from great marine sediments laid down during the Jurassic epoch (180 million years ago) through the Miocene epoch (25 million years ago), while Napa County lay beneath the primordial sea.

Most of the sedimentary rock exposed in Napa County is sandstone, but there also are sills, limestones and conglomerates.

Later formations and mineralizations created rocks in many parts of Napa County with high magnesium contents. Soils in these areas support mostly shrubby-type vegetation.

During Pliocene times (one million to 10 million years ago), the Napa region was raised from beneath the sea. Great volcanic activity in the area covered over the existing sedimentary formations.

At that time, the Howell and Mayacamas mountains, bordering the east and west sides of the Napa Valley, respectively, were covered by layers of volcanic rock hundreds of feet thick.

Toward the end of the volcanic period, the geologic process of folding increased and the Mayacamas Ridge and the Napa Valley were formed. Through thousands of years of weathering, the layers of volcanic rock have been eroded to form ridges and streams.

Contrary to popular belief, the mountain at the head of the Napa Valley — Mt. St. Helena — is not a volcano.

That belief, according to a ranger at Bothe-Napa Valley State Park, is based on mistaken identity.

"At certain angles, you look at the mountain and it looks like a volcano and you get on the other side and it doesn't look like a volcano at all," said Ranger Bill Verdery.

Because of the mountain's cone shape, many have mistaken the 4,344-foot Mt. St. Helena for a volcano, he said.

There are volcanic rocks in the area, but they are much too old to have been produced by the relatively young Mt. St. Helena.

The earlier volcanic activity probably accounts for the Petrified Forest near Calistoga. Trees there were covered with ash, petrifying the wood.

Mineral resources, important in the history of Napa County, resulted from both the sedimentary and volcanic processes.

These minerals include limestone, coal, manganese, serpentine, silver, spotian, perlite, sulphur, gold, quicksilver, sand and gravel.

Because of the abundance of minerals, both thermal and non-thermal mineral springs are found in many places in the county.

These waters are used commercially as baths and as a source of bottled mineral water.

Climate

Napa County enjoys a typical Mediterranean climate; warm, dry summer days with cool, often foggy evenings and mild, wet winters.

Local topography and the distance from San Pablo Bay determine distinct microclimates that can greatly affect wildlife and vegetation.

Many grape varieties can be grown in Napa County because of unique
combinations of soil, climate, and technology in many small microclimates.

The broad opening of the Napa Valley onto the bay permits marine breezes and summer fogs to enter the lower valley. But at the head of the valley, and on the mountain slopes, other influences cause different temperatures and rainfall patterns. The highest temperatures have been recorded on the valley floors, far from the coastal and marine influences. Freezing temperatures have been recorded throughout the county.

More than 70 percent of the rainfall in Napa County falls between December and March, and only 3 percent falls between June and September. Annual rainfall totals vary according location: 22 to 23 inches in Napa, 36 to 37 inches in Calistoga, 44 to 46 inches at Bothe-Napa Valley State Park, and 59 to 60 inches at Mount St. Helena.

**The Napa River and its tributaries**

The Napa River has its origins at the foot of Mt. St. Helena. It flows south for 40 miles along the floor of the valley and eventually empties through the Napa Marsh into San Pablo Bay.

The Napa Marsh is home to many species of plants, waterfowl, and small mammals. Wetlands throughout the United States and around San Francisco Bay have diminished in recent decades, due to development on their shores. State and federal agencies have made the reclamation of many of these wetlands, including the Napa Marsh, a high priority.

Rare wildlife species located in the Napa River Marshes are the California Clapper Rail, Black Rail, Salt-Marsh Harvest Mouse, and Peregrine Falcon.

Virtually half the acreage in Napa County — 242,900 acres — lies in the Napa River watershed. There are no natural lakes in Napa County. The most notable geographic feature on the eastern side of the county is Lake Berryessa, a large, man-made lake formed behind Monticello Dam in 1957. The dam was built to meet increasing needs for water storage and flood control. A lack of snow to store moisture for the summer months and a high concentration of rainfall during the winter months contribute to great variation in water flows in the rivers and streams of Napa County; many almost disappear in late summer, yet reach flood stages in the winter months.

**Vegetation**

One type of vegetation found throughout Napa County is the mixed evergreen forest. Vegetation in this broad category of forest includes tanbark oak, oak, poison oak, madrone, scrub oak, bear grass, and bracken. Also, blueberry, deer tongue, fern, wild grape, and California bay.

The rare and endangered ruby lily and redwood orchid are found in the mixed evergreen forest.

The most inland stand of redwoods in California is found on the Howell Mountains, about 42 miles from the coast. But the majority of inland coast redwoods are found along the creeks, canyons, and northern slopes of the Mayacamas Mountains.

Chaparral, or brushland, another category of vegetation, is composed of several species of shrubs, sometimes growing in pure stands and sometimes mixed. Much of the chaparral in Napa County is found at the higher elevations on dry sites and south-facing slopes. It is characterized by a predominance of manzanita. The shrubs that comprise the chaparral are low, averaging between three and six feet tall.

Large sections of the Napa Valley’s natural vegetation were replaced by agriculture.
orchards and grazing lands, and later, by vineyards and wineries.

This has occurred not only on the valley floor, but also in the mountains and foothills that border the valley.

Heavy logging during the 19th century virtually eliminated the pure stands of Douglas-fir forest that once covered the Mayacamas Mountains. This logging continued into the 20th century, when Napa Valley timber was used to help rebuild San Francisco after the 1906 earthquake and fire.

Wildlife

Although Napa County once possessed a wealth of diverse wildlife, human activities, particularly in the Napa Valley and near Lake Berryessa, have greatly reduced the number and variety of animal populations.

Early settlers reported that it was not unusual to see 50 or 60 grizzly bear in one day. Gigantic elk were found in great numbers in marshy areas along the river.

Salmon were abundant in the Napa and Carneros rivers and as recently as 1913, river otter inhabited the Napa River.

For early settlers, hunting was an economic necessity. Most of the large animals were used for food, or were destroyed or driven away because they were a danger to crops, livestock or settlements.

The ring-tailed cat, California mountain lion, California wildcat, raccoon, gray fox, California coyote, once numerous on the valley floor, have been pushed into the rugged and relatively inaccessible highlands.

The pioneers were not altogether responsible for the decrease in wildlife. Contemporary Napa County residents, with their agricultural ventures, domesticated pets, livestock and development, have reduced wildlife and vegetative habitats.

Although smaller animals such as rodents, rabbits, squirrels and chipmunks are still abundant, the only large animal now to be found near the foothills and valley floor is the black-tailed deer.
The Napa Soil Survey is online!

Visit our website at:

www.naparcd.org
www.ca.nrcs.usda.gov/mIra/NapaSS/napass.html

Now you can access all of the soil maps and land resources data found in the published survey manual and much more!

Here's a sampling of the extensive information you'll find at this interactive site:

- Orthophoto soil maps
  - County-wide coverage available for download

- Detailed soil series descriptions and representative soil profiles

- Full color general soils map of Napa County

- Soil physical features and engineering classifications (table format)

- Interpretive maps, illustrating selected soil quality features

- Soil use and management

- Climatic data

For more information, contact:

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Kelly Gin, Soil Conservationist
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1303 Jefferson St., Suite 500B,
Napa, CA 94559
(707) 252-4189
The physical geography of an area is typically described as a function of its relief, topography, size, geographic location, regional and/or local climate, rock formations and geologic structure, geomorphology, surface soils, natural vegetation, hydrology (surface and occasionally subsurface), and degree of anthropogenic disturbance. Methodology has been further defined by the subdisciplines and allied disciplines for collecting and analyzing climatic data, sampling and describing soils, mapping landforms, etc. Many books include procedures for the above methods, although no single book truly integrates all physical geography techniques, not even for field (yet alone laboratory) techniques. The technical literature is exhaustive on these subjects, as methods are newly refined and redefined.

A person skilled in physical geography field methods should be able to go into the field and map the local climates, soils, geomorphic units, vegetation, and surface hydrology of the area. This mapping can be highly subjective (e.g., based on personal experience), but can also be very objective. The recommended methodology is quantitative or objective in nature, with mapped units determined after analytical discrimination of their components. As viticultural areas are of political and economic significance, physical geographic phenomena should be as objectively and quantitatively defined as possible. For example, instead of simply standing on a valley floor and looking up at the hillsides and saying "yeh, that's an oak woodland", then sketching such on a map, the geographer can do detailed sampling of all the vegetation/plant communities using quadrats, line-intercepts (transects), or a plotless sampling technique to determine plant density, dominance and frequency of occurrence, etc. Statistical analysis of these data can then be done using multivariate procedures to differentiate plant communities. Unit boundaries or margins and ecotones of the different plant communities can then be mapped.

Soils and geomorphic mapping should go hand in hand, as soils are usually mapped according to geomorphic surfaces or units. For example, soils on a relatively old alluvial fan are usually better developed (as reflected by their horizonation, clay content, etc.) than on a younger fan. It is also true that there is inherent variability of soils on a fan surface, as fans are constructed through a series of debris flows and other mass movement events. Subsoils are even more strongly a function of geomorphic unit (i.e., deposit) or bedrock itself. The geographer should therefore first identify geomorphic surfaces in and outside of the proposed viticultural area under question. This is mostly easily done by the trained observer using air photos or other remote imagery, topographic maps, and geological maps in tandem. Soil pits or trenches should then be dug within all geomorphic units and along their margins. Unlike the standard sampling done by the U.S. Soil Conservation Service to 60 inches, it is recommended that an exposure is opened up into the subsoil, so geomorphic units may also be defined. Soils are then described in the field using standard procedures (Singer and Janitsky, 1986). Additional laboratory analysis of texture, metered pH, cation-exchange capacity, etc. may yield valuable data. Soils can then be classified and mapped.

Surface and near-surface hydrology is determined through analysis of soil moisture-holding capacity, groundwater table depth, analysis of drainage pattern and density, regularity of streamflow, etc. Some of these data are obtained in conjunction with the research on soils, subsoils and geomorphic units. Detailed collection of field data on stream discharge, etc., is usually not necessary, due to irrigation practices modifying the natural water balance.

The climate or climate variability of the area can be assessed in the field using topographic variables and proxy indicators of climate. Topo- and microclimates are defined through analysis of slope angles, slope aspect, elevation, topographic shading of the solar disc, analysis of the vegetation canopy, etc. In a relatively undisturbed and unplanted area, the natural vegetation can be an excellent indicator of topo- and microclimate. In many areas, detailed observational networks are not available to provide instrumental data on temperature, precipitation, wind, etc., so the researcher must work with proxy and topographic indicators of climate. In areas where instrumental data is available, this should be analyzed and summarized using standard procedures and integrated with the topographic and proxy climatic data. The establishment of correlations (or statistical relationships) between instrumental and proxy data will allow more accurate climate mapping beyond the region where instrumental data are available.

Data on all of these aspects of the physical geography of the viticultural area in question should then be integrated to look for spatial patterns in the data. This may be done qualitatively or quantitatively using statistical methods of spatial correlation and preferably geographic information systems. It is unlikely in most regions, however, that a nice neat correspondence will occur between mapped climatic units, geomorphic surfaces, soils, hydrologic systems, and plant communities, even though these natural features are highly interdependent (Jenny, 1941; Major, 1966; White, et al, 1984). Systems analysis can be logically applied to this data, with viticultural areas analyzed as geographic systems which are bounded, functionally and structurally organized, and integrated (White, et al., 1984; Elliott-Fisk, 1988).
The Carneros and Howell Mountain viticultural areas are recognized as unique Californian appellations. Professors Noble and Elliott-Fisk of the University of California, Davis, propose to assess the diversity and coherency of the geography (especially climate, geomorphology, and soils) of these and other selected viticultural areas in northern California. Trace and essential element analyses of soils, vegetative tissues, berries and wines will be correlated with the geographical data to link the wines to the vineyard environment. The ions available for uptake in the soils will be compared with those found in the petioles and berries, with attention focused on those known to have effects on berry metabolism. Small lot wines made from selected sites and commercial wines from the studied viticultural areas will be evaluated by sensory descriptive analysis and by standard chemical tests. By multivariate statistical analyses of the sensory, chemical and geographical data, factors which permit classification of the regions and contribute to the distinctiveness of the wines will be determined. This will serve as a model for further investigations.
Soils and "terroir" are important viticultural parameters. The subsurface environment of the soils and subsoils develops over long periods of time and is inherited by viticulturalists. Although farming practices can modify the soil structure and horizonation to some extent, with the addition of fertilizers and other chemical products changing the upper foot or so of the soil, the viticulturalist is often forced to accept what the subsurface environment provides, as the vines root to great depths where possible.

The soils of Napa Valley are a function of its climate, soil parent materials, topography, organisms (natural vegetation and soil fauna), and time. The role each of these variables plays changes from site to site, but in an overall sense, time and parent material control soil variations within Napa Valley. This is because Napa Valley has an active and diverse geological history, with the most important influence on soils the Late Cenozoic (e.g., Quaternary) dynamics of the Napa River system and San Pablo Bay. The present Napa River system may have been part of a larger hydrological system linking the Russian River and streams on the Santa Rosa Plain (Sonoma County) to the Napa River prior to major tectonic disturbance (with the Russian River "gorge" of recent origin). These events may have been associated with formation of the Sonoma Volcanics. High, raised terraces are evidence of this in several places in Napa, Knights and Alexander Valleys.

San Pablo Bay has transgressed and regressed through at least the lower half of the valley (Yountville south) several times in the past. This resulted in the deposition of bay muds which vary from carbonate to organic rich as potential soil parent material. Most of the soils of the Carneros area have these muds as the soil parent material. Variations in the flow of the Napa River and its tributaries (and the migration of its stream courses across the floor of the Napa Valley) have also resulted in the deposition of river and fan sediments of different ages, which vary in texture from fine clays and silts to coarse gravels.

Superimposed on this are the different bedrock types from which these sediments are derived, with the Sonoma Volcanics (principally rhyolite, dacite and andesite) in the northern and eastern parts of the valley (e.g., Calistoga area and Vaca Range), the marine sedimentary Franciscan and Great Valley formations in the west (i.e., Mayacamas Range), and the young Quaternary bay muds in the south. Thus, the depositional lowland soils in Napa Valley are extremely variable in their mineralogy, chemistry, texture and structure. The oldest soils in Napa Valley are found at high elevations on ridges and terraces, and are clay loams of the Aiken and as yet undesignated series. Other slope and valley floor soils are of intermediate age, with soils immediately along the Napa River of recent origin.

Through analysis of the soil geomorphology of the region, ages can be assigned to soils and used to deduce the geological and environmental history of Napa Valley. Knowledge of this variation of soils in the valley should aid viticulturalists in vineyard selection and management.
GEOLOGY AND GEOMORPHOLOGY OF NAPA VALLEY

**PAST**

Deposition of sediments offshore; formation of marine sedimentary rocks

- Rocks folded; pre-Napa Valley forms
- Volcanism: Sonoma Volcanics cover uplands
- Faulting: formation of hills within valley

Powerful Napa R. erodes and cuts valley, with hills forming rock islands in river channel

As climate changes through wet/dry and warm/cool cycles, sea-level rises and falls and the Napa River flow rises and falls. River and fan sediments are deposited at different periods of time. Continued faulting also influences the river and the valley.

**PRESENT**

GEOLOGY AND GEOMORPHOLOGY

1. Napa Valley is a synclinal valley of late Cenozoic age formed primarily from folded Cretaceous and Jurassic marine sedimentary rocks.
2. A veneer of Miocene to Quaternary age volcanic rocks (i.e., the Sonoma Volcanics) covers uplands, especially on the eastern side of the valley.
3. Post-Miocene faulting resulted in the formation of hills along the valley flanks which stand above more recent alluvial deposits. Many of these hills were modified by erosion as rock islands within the former channel and floodplain of the Napa River and its tributaries.
4. Quaternary climate change resulted in tremendous fluctuation in the discharge of the Napa River system, as well as in sea-level fluctuations of San Pablo Bay. This resulted in several "cycles" of river aggradation and degradation. Alluvial fans were also built across portions of the Napa River floodplain by mountain streams (such as Dry Creek, Soda Creek, and Rector Creek), resulting in the displacement of the main channel of the Napa River through time. Tectonic disturbance no doubt also influenced the gradient of the valley and the river's position within the valley.

**GEOMORPHIC UNITS**

<table>
<thead>
<tr>
<th>Inferred Age*</th>
<th>Former Napa River Channel</th>
<th>Rector Canyon Fan</th>
<th>Old Dry Creek Fan</th>
<th>Older Dry Creek Fan</th>
<th>Older Hinman Fan</th>
<th>Soda Canyon Fan</th>
<th>Dry Creek Fan</th>
<th>Lake Hinman Fan</th>
<th>Milliken Creek Fan</th>
<th>Chimney Rock Fan</th>
<th>Napa River Terrace</th>
<th>Napa River</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1 Ma</td>
<td>~150,000 - 15,000 yr B.P.</td>
<td>25,000 - 15,000 yr B.P.</td>
<td>25,000 - 15,000 yr B.P.</td>
<td>15,000 yr B.P. - present</td>
<td>15,000 yr B.P. - present</td>
<td>15,000 yr B.P. - present</td>
<td>recent</td>
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<tr>
<td>~400,000 - 150,000 yr B.P.</td>
<td>~150,000 yr B.P.</td>
<td>25,000 - 15,000 yr B.P.</td>
<td>15,000 yr B.P. - present</td>
<td>15,000 yr B.P. - present</td>
<td>15,000 yr B.P. - present</td>
<td>15,000 yr B.P. - present</td>
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* Inferred from work elsewhere on the geomorphic history of California (not direct dates).
THE QUATERNARY
[1.7 mya to the present]
[recent Earth history, as Earth is ~4.6 bya]

High magnitude/high frequency global climatic change
~17 glacial-interglacial cycles
Glacial ~90,000 yrs duration (extension of glaciers)
Interglacial ~10,000 yrs duration (contraction of glaciers)

Glacial: Sea-level drops as much as 125m.
Interglacial: Sea-level rises as much as 10m.
(This is in reference to our present interglacial sea-level.)

SEA-LEVEL DROP:
1. Regression of SF and San Pablo Bays (emptying of bay).
2. Napa River downcuts to lower base level.
3. Terraces cut into floodplain.
4. Napa River may meander and deposit alot of fine sediment if this accompanies a precipitation increase (wet glacial climate: ~130,000 ybp – cold, wet).
5. Napa River may braid and deposit alot of coarse sediment if this accompanies a precipitation decrease (dry glacial climate: ~18,000 ybp – cold, dry).

SEA-LEVEL RISE:
1. Transgression of Bay inland (~1/2 way up Napa Valley?).
2. Lower course of Napa River flooded.
3. Deposition of fine and coarse material in lower valley.
4. Progression of coastal salt marsh and subtidal communities up the valley. Differences in productivity and infauna of these communities lead to differences in organic and calcium content, color, texture, etc. in the deposits.
OZOLOOIC HISTORY

In Napa and Sonoma Valleys the decipherable geologic history begins in the Jurassic. The Jurassic to Miocene history of the California Coast Ranges in Napa and Sonoma Valleys does not bear a direct relation to the present ground-water bodies and the existing hydrologic problems, and is therefore summarized only briefly. This summary has been drawn from more complete accounts, principally by Reed (1933), Taliaferro (1943a, b), Weaver (1949), and Howard (1951). The geologic history from the Pliocene to Recent is directly related to the occurrence, source, and movement of most of the usable ground water in Napa and Sonoma Valleys and is therefore covered more fully.

In late Jurassic time, detritus from a western source accumulated in a shallow geosynclinal sea, which covered the area now occupied by Napa and Sonoma Valleys, to become the sedimentary and metamorphic rocks of the Franciscan group, or the Franciscan-Knox-Tille group of Taliaferro. During and after the deposition of these sediments they were extensively intruded and locally covered by ultrabasic igneous rocks in the form of dikes, sills, and flows now wholly serpentinized. Throughout the Coast Ranges the Jurassic eroded with uplift and local warping, but the geosyncline was not destroyed.

During the Cretaceous period, fine-grained detritus accumulated in the same depression. These sediments became the Shasta series and Chico formation. Deposition was brought to a close near the end of the period by folding and uplift accompanying a minor orogenic movement. During the Tertiary time the sea again invaded the area of Napa and Sonoma Valleys and mud, silt, and sand were deposited. During this time there were several transgressions and regressions of the sea, and some minor deformation, which separated the sediments into distinct lithologic groups now recognized as the Capay, Domencine, Markley, San Ramon, Monterey, Briones, Cierbo, and Neroly formations (Weaver, 1949).

The material that formed these early rocks was derived largely from the Sierra Nevada to the east, and, as a result the mineral composition of the detritus at most places, is akin to the Sierran rocks rather than to those of the Coast Ranges. During middle Miocene time a weak orogenic movement began a period of uplift in the Coast Ranges region; by the end of Miocene time a long, low coastal range had risen west of Napa and Sonoma Valleys. This range greatly modified the conditions of deposition in succeeding epochs.

The Miocene uplift probably extended into the early Pliocene and brought about widespread uplift and withdrawal of the sea from most of the region.

Early and middle Pliocene time was one of relative stability, but it was brought to a close by the most important episode of mountain building since the late Jurassic. Movements that accompanied this episode, which ultimately formed the modern Coast Ranges, reached a climax in the late Pliocene or early Pleistocene (Taliaferro, 1951, p. 146), and have continued intermittently to the present. Uplift probably took place at slightly different times in different parts of the region. Thus, even though erosion of the land surface at any one place in the northern Coast Ranges began immediately after the elevation, the resulting sediments deposited in different areas are not necessarily fully contemporaneous. Also, the exact dating of the disturbance is open to question because the dating by invertebrate fossils is not in agreement with that by vertebrate finds (Taliaferro, 1951, p. 142).

In early Pliocene time, some mud and sand of the Petaluma formation may have been deposited in the western part of Sonoma Valley. Although throughout most of the Pliocene the land in Napa and Sonoma Valleys was above sea level, the prevailing crustal unrest was expressed by extensive volcanic activity, and large areas were covered by many interbedded flows of basalt, andesite, and rhyolite, and by blankets of pumice and ash. During periods of relative quiescence, gravel, sand, and clay were deposited on the volcanic terrane. Also, in small areas, fresh- or brackish-water lakes were formed in which large numbers of diatoms grew, their skeletons ultimately forming beds of diatomite or diatomaceous clay. All these water-laid deposits were buried by pumice, ash, or flows. The last extrusions were widespread tuffs and flows of rhyolitic composition. These volcanic rocks and associated deposits comprise the undifferentiated Sonoma volcanics, the diatomaceous member, and the St. Helena rhyolite member.

During the extrusion of the Sonoma volcanics a marine embayment may have extended eastward south of the Sonoma Mountains and possibly south of the Mayacamas Mountains.
Late in the Pliocene, and continuing into the early Pleistocene, the Coast Ranges region was uplifted, folded, and faulted. The Sonoma volcanics, including the St. Helena rhyolite member, were folded and faulted into synclinal and anticlinal structures. Napa and Sonoma Valleys were broadly outlined by the formation of the ancestral Howell, Mayacmas, and Sonoma Mountains, and coarse sediments derived from the mountain areas began to accumulate in the depressions.

This alluvial sand, gravel, and mud, whose deposition continued into the early Pleistocene in the newly formed Napa and Sonoma synclinal areas, became the Huichica and Glen Ellen formations. The sediments first deposited were derived largely from the Sonoma volcanics and hence are composed mainly of volcanic detritus. Parts of these formations are undoubtedly contemporaneous. Some folding continued during and after the deposition of these beds, as they are noticeably tilted at most places.

This deposition was brought to a close in middle or late Pleistocene time by general uplift, and the region was subjected to erosion. Alluvial fans, terrace deposits, and cut terraces related to several cycles of differential movement between the land and sea were formed. These sediments are the undeformed deposits mapped as older alluvium and undifferentiated terrace deposits. Because both land and sea level moved independently during the Pleistocene, it is impossible to determine the relationship of these deposits to each other or to determine which of the deposits are related to a change in land level and which are related to a change in sea level.

Late in the Pleistocene, during one of the periods when sea level was several hundred feet lower than at present, streams cut valleys thought to be graded to a main river flowing out through the Golden Gate. A subsequent rise in sea level, thought by Louderback (1951, p. 88) to have occurred during the third interglacial stage, formed San Francisco Bay. Whether or not this dating is correct, the latest activity in the region has been continued erosion in most of the land area, and corresponding deposition of sediments in and immediately bordering the bay.
Figure 4.3  The provenance of sedimentary rocks.

Figure 4.4  Relation between Wentworth-Lane class limits and the phi-scale.

A FORM
Figure 4.17  Simplified representation of an idealized sedimentary sequence during offlap showing identity of vertical sequence and spatial outcrop pattern.
Figure 11.1 A diagrammatic sketch showing the internal structure of a typical alluvial fan.

Figure 14.2 Several types of river terraces: the diagrams to the right indicate schematically the vertical (cut and fill) and horizontal movement of the river during the successive phases of terrace formation; for example, overslag terraces (Dutch: overslaugh - 'pass over') are formed by a simple succession of fill and partial cut.
Source: Zonneveld, 1973, figure 1, p. 278.
Figure 14.9 Physiography and facies of a braided alluvial channel system, where sedimentation occurs in a rapidly shifting complex of channels; key is given in Figure 14.10.

Figure 14.10 Physiography and facies of an alluvial floodplain produced by meandering channels.